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Research & Development

NOVEMBER 1984

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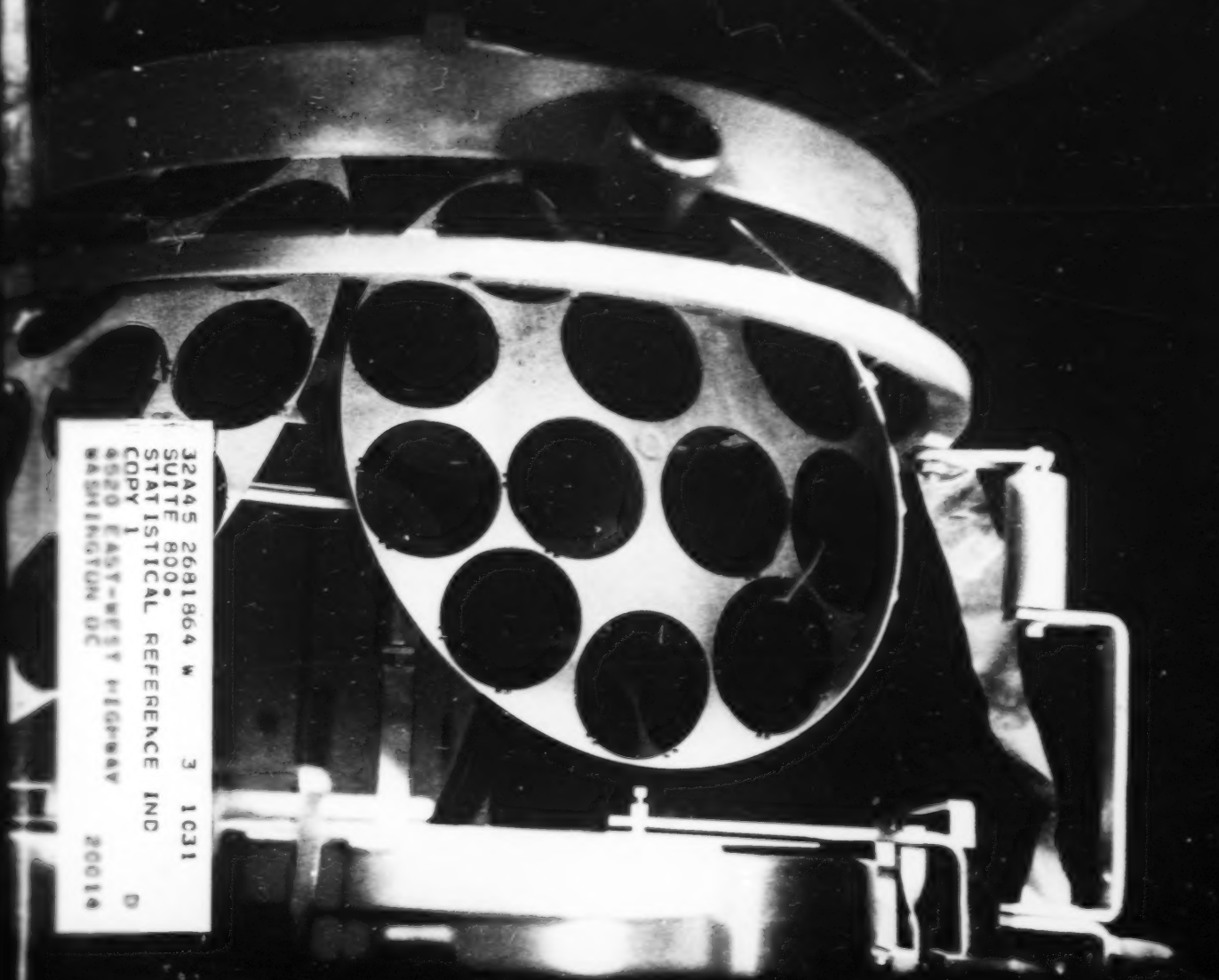

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Vacuum Show issue

Research & Development

SERVING THE $186-BILLION WORLDWIDE R&D INDUSTRY

High-vacuum applications — see pp 123, 130, 138, 146, 152.

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ABOUT THE COVER

Sputter deposition is one of the methods used in the fabrication of modern microcircuitry. General Electric R&D Center, Schenectady, NY, uses this high-vacuum tool to lay down microscopic deposits of metal for conducting pathways that connect thousands of transistors and other circuit elements in a chip with an area less than that of a fingernail.

Manufacture of these complex chips may require more than 100 steps, each depending on highly sophisticated vacuum-processing equipment.

The cover photo was supplied by General Electric R&D Center.

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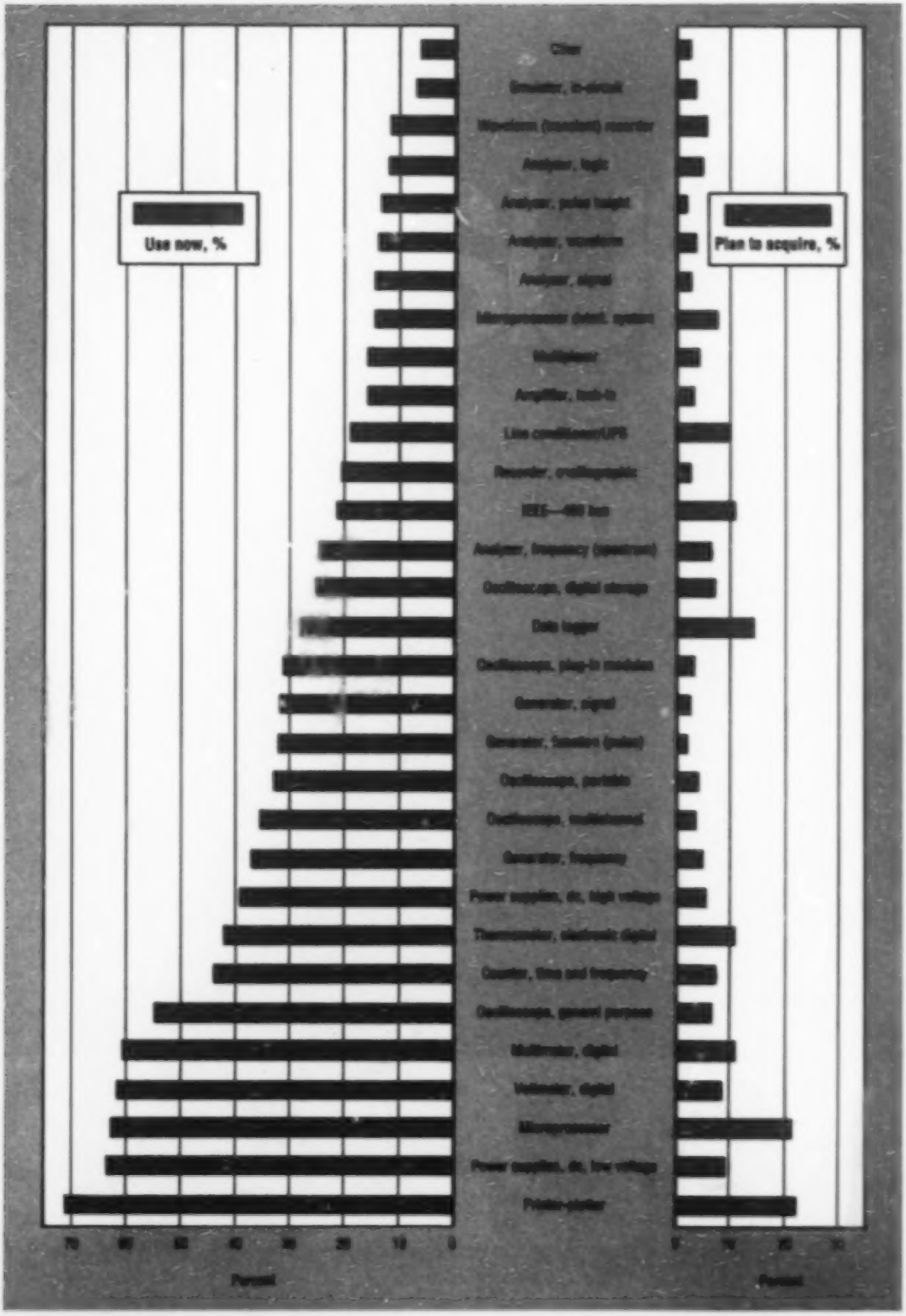

Use now, %
Plan to acquire, %
Other
Emulator, in-circuit
Waveform (transient) recorder
Analyzer, logic
Analyzer, pulse height
Analyzer, waveform
Analyzer, signal
Microprocessor (dvlpt. system)
Multimeter
Amplifier, lock-in
Line conditioner/UPS
Recorder, oscillographic
IEEE—488 bus
Analyzer, frequency (spectrum)
Oscilloscope, digital storage
Data logger
Oscilloscope, plug-in modules
Generator, signal
Generator, function (pulse)
Oscilloscope, portable
Oscilloscope, multichannel
Generator, frequency
Power supplies, dc, high voltage
Thermometer, electronic digital
Counter, time and frequency
Oscilloscope, general purpose
Multimeter, digital
Voltmeter, digital
Microprocessor
Power supplies, dc, low voltage
Printer-plotter
70
60
50
40
30
20
10
0
Percent
0
10
20
30
Percent

C.J. Mosbacher
Executive editor, *R&D*

TRENDSURVEY

Use of electrical and electronic instruments

Plans to acquire new instruments rebound with increases in almost all sectors. Digital instruments lead the way in Trendsurvey.

LAST YEAR'S Trendsurvey indicated a drop of more than 12% in plans to acquire new electrical and electronic instruments within a year of the survey for use in R&D. This year's results are drastically different; plans to acquire have increased dramatically, according to the 898 *Research & Development* readers who replied to the survey. Average present use of 30 categories of instruments was 32.1% compared to 32.2% last year—a drop of 0.3%. Average plans to acquire rose from 6.2% last year to 7.3% now, an increase of 17.7%.

But this does not take into account the fact that respondents this year have different demographic profiles from those to last year's study. For example, this year more engineers, fewer physical scientists, and more life scientists and medical researchers responded.

When these differences, together with differences in employers and job functions are considered and adjusted to state this year's results on the basis of last year's demographics, present use drops to 31.6% and plans to acquire to 7.1%. These "normalized" results show a drop of 1.9% in present use and an increase in plans to acquire of 14.5% over last year.

Another indication of increasing plans to acquire is the more than 12% decrease in respondents having no plans to acquire, from 46.6% to 41.5%. That's even lower than the comparable figure for 1982 — 44.4%.

One possible cause for this present increase in instrument acquisition plans is the increased availability of new digital instrumentation and systems that combine instruments and data processing. The highest ranking in growth rates goes to digital; as do the highest rankings based on plans to acquire, only without consideration of present use.

The top ten categories based on total-sample plans to acquire are: printer-plotters, microprocessors, data loggers, digital multimeters, digital thermometers, IEEE 488 bus, line conditioners-universal power supplies, dc low-voltage power supplies, digital voltmeters, and microprocessor development systems.

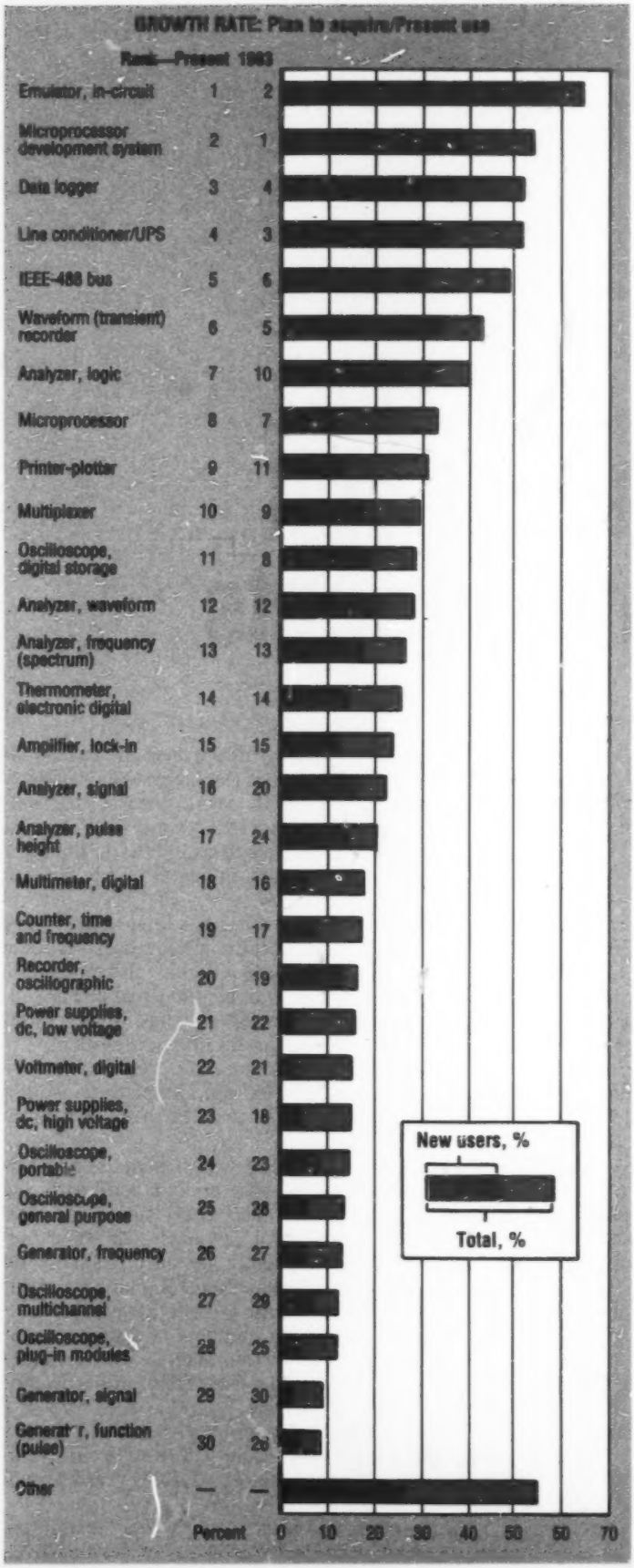
Results of the Trendsurvey are presented graphically on these pages. Present use and plans to acquire are graphed on the facing page as a percent of total respondents.

Growth rates calculated with present use of a particular instrument as the base are summarized in the chart on the next page. This chart shows the total growth rate and the rate for new users—those who indicated they do not presently use an instrument but who plan to acquire it within a year. Rankings this year and last also are given on the growth rate chart.

Complete data giving numbers of respondents as well as percentages for the total sample and disciplines are given in the table on the last page of this article for both growth and growth rate.

Average present use and plans to acquire vary among the demographic groups. The following paragraphs summarize these averages for this year's Trendsurvey and for last year's.

By discipline, and without the "Other" instrument category which is not included in any of the data given


GROWTH RATE: Plan to acquire/Present use
Rank—Present 1983
Emulator, in-circuit 1 2
Microprocessor development system 2 1
Data logger 3 4
Line conditioner/UPS 4 3
IEEE-488 bus 5 6
Waveform (transient) recorder 6 5
Analyzer, logic 7 10
Microprocessor 8 7
Printer-plotter 9 11
Multiplexer 10 9
Oscilloscope, digital storage 11 8
Analyzer, waveform 12 12
Analyzer, frequency (spectrum) 13 13
Thermometer, electronic digital 14 14
Amplifier, lock-in 15 15
Analyzer, signal 16 20
Analyzer, pulse height 17 24
Multimeter, digital 18 16
Counter, time and frequency 19 17
Recorder, oscillographic 20 19
Power supplies, dc, low voltage 21 22
Voltmeter, digital 22 21
Power supplies, dc, high voltage 23 18
Oscilloscope, portable 24 23
Oscilloscope, general purpose 25 28
Generator, frequency 26 27
Oscilloscope, multichannel 27 29
Oscilloscope, plug-in modules 28 25
Generator, signal 29 30
Generator, function (pulse) 30 26
Other — —
New users, %
Total, %
Percent 0 10 20 30 40 50 60 70

in these paragraphs, present use averages 37.7% and plans to acquire average 8.9% for engineering, 30.1% and 6.1% for physical science, and 19.3% and 4.8% for life science and medicine. Comparable data last year were 38.9% and 8.7% for engineering, 28.5% and 5.7% for physical science, and 22.6% and 4.3% life science and medicine.

By employer, industry averages 32.3% present use and 7.4% plans to acquire, universities 35.2% and 7.9%, nonprofit organizations 28.4% and 7.2%, medical research centers 29.9% and 5.3%, and other organizations including government, 29.2% and 6.0%. For last year, comparable data are 30.8% present use and 6.9% plans to acquire for industry, 37.1% and 6.8% for universities, 35.9% and 10.2% for nonprofit organizations, 26.2% and 8.7% for medical research centers, and 31.1% and 6.0% for other organizations including government.

Corporate officers have average present use of 26.1% and average plans to acquire of 13.1%, R&D executives 37.0% and 10.5%, project managers 33.7% and 9.7%, professional staff 32.1% and 5.8%, and others 28.1% and 6.1%. Comparable figures for 1983 were 32.6% and 9.3% for corporate officers, 35.0% and 9.7% for R&D executives, 34.5% and 7.9% for project managers, 31.8% and 6.3% for professional staff, and 28.4% and 6.9% for others.

As noted earlier, the demographics producing these results vary from year to year. In this year's survey, 5.6% are corporate officers, 9.0% R&D executives, 15.9% project managers, 62.9% professional staff, and 5.5% other titles. Last year, the corresponding numbers were 3.0%, 7.0%, 17.1%, 66.3%, and 4.2% respectively. Note that the totals are less than 100% because some respondents did not answer all questions.

By discipline, 47.4% of this year's replies listed engineering, 35.5% physical science, and 14.4% life science or medicine. Comparable figures last year were 43.6%, 40.7%, and 12.2%.

Industry accounted for 53.6% of the replies this year, universities 21.3%, nonprofit organizations 6.1%, medical research centers 3.3%, and others 14.0%. Comparable data last year were 52.6%, 19.6%, 7.4%, 2.6%, and 14.9%.

Geographically, replies correlate well with R&D circulation, with 6.7% New England, 14.5% Middle Atlantic, 18.9% East North Central, 6.5% West North Central, 14.8% South Atlantic, 2.4% East, 5.9% West South Central, 4.3% Mountain, and 17.6% Pacific, with 8.4% not providing a zip code.

As with earlier Trendsurveys, this study was conducted by including a prepaid reply card in a May mailing to *R&D* subscribers in the United States. R&D

PRESENT AND PLANNED USE: Data from 898 respondents	Use now								Plan to acquire within 1 year								Growth rate = plan to acquire ÷ by present use			
	Total, 898		Engineering, 426		Physical science, 319		Life science or medicine, 129		Total, 898		Engineering, 426		Physical science, 319		Life science or medicine, 129		Total	Present users who plan to acquire		New users
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	%	No.	%	%
Amplifier, lock-in 1983	141	15.7 16.9	60	14.1	71	22.3	7	5.4	33	3.7 3.0	14	3.3	16	5.0	2	1.6	23.4	17	12.1	11.3
Analyzer, frequency (spectrum) 1983	220	24.5 24.4	142	33.3	63	19.7	11	8.5	59	6.6 5.5	42	9.9	13	4.1	3	2.3	26.8	21	9.5	17.3
Analyzer, logic 1983	115	12.8 14.6	85	20.0	24	7.5	6	4.7	46	5.1 4.1	31	7.3	11	3.4	4	3.1	40.0	9	7.8	32.2
Analyzer, pulse height 1983	120	13.4 14.6	46	10.8	59	18.5	12	9.3	24	2.7 1.7	11	2.6	10	3.1	2	1.6	20.0	7	5.8	14.2
Analyzer, signal 1983	130	14.5 12.8	78	18.3	38	11.9	10	7.8	28	3.1 1.7	19	4.5	5	1.6	3	2.3	21.5	8	6.2	15.4
Analyzer, waveform 1983	125	13.9 15.0	78	18.3	36	11.3	10	7.8	35	3.9 3.4	26	6.1	7	2.2	2	1.6	28.0	10	8.0	20.0
Counter, time and frequency 1983	402	44.8 46.5	242	56.8	118	37.0	32	24.8	68	7.6 7.1	38	8.9	19	6.0	7	5.4	16.9	40	10.0	7.0
Data logger 1983	258	28.7 26.0	140	32.9	82	25.7	29	22.5	132	14.7 11.8	79	18.5	37	11.6	13	10.1	51.2	39	15.1	36.0
Emulator, in-circuit 1983	56	6.2 4.6	39	9.2	14	4.4	3	2.3	36	4.0 2.3	30	7.0	4	1.3	2	1.6	64.3	3	5.4	58.9
Generator, frequency 1983	339	37.8 39.8	220	51.6	88	27.6	26	20.2	42	4.7 3.6	24	5.6	12	3.8	2	1.6	12.4	24	7.1	5.3
Generator, function (pulse) 1983	287	32.0 32.1	172	40.4	91	28.5	16	12.4	25	2.8 3.4	15	3.5	7	2.2	2	1.6	8.7	13	4.5	4.2
Generator, signal 1983	287	32.0 29.9	181	42.5	83	26.0	16	12.4	27	3.0 2.6	16	3.8	7	2.2	1	0.8	9.4	19	6.6	2.8
IEEE-488 bus 1983	192	21.4 21.5	105	24.6	72	22.6	10	7.8	94	10.5 8.1	46	10.8	36	11.3	7	5.4	49.0	36	18.8	30.2
Line conditioner/UPS 1983	175	19.5 15.4	93	21.8	58	18.2	20	15.5	89	9.9 7.3	52	12.2	28	8.8	7	5.4	50.9	31	17.7	33.1
Microprocessor 1983	570	63.5 63.4	271	63.6	211	66.1	75	58.1	190	21.2 19.8	102	23.9	58	18.2	27	20.9	33.3	130	22.8	10.5
Microprocessor development system 1983	131	14.6 14.1	79	18.5	37	11.6	10	7.8	71	7.9 8.7	47	11.0	17	5.3	4	3.1	54.2	22	16.8	37.4
Multimeter, digital 1983	547	60.9 59.9	298	70.0	193	60.5	45	34.9	97	10.8 10.1	49	11.5	39	12.2	7	5.4	17.7	70	12.8	4.9
Multiplexer 1983	141	15.7 14.2	91	21.4	36	11.3	8	6.2	42	4.7 4.1	23	5.4	11	3.4	6	4.7	29.8	17	12.1	17.7
Oscilloscope, digital storage 1983	223	24.8 22.7	144	33.8	63	19.7	12	9.3	63	7.0 7.0	45	10.6	13	4.1	4	3.1	28.3	20	9.0	19.3
Oscilloscope, general purpose 1983	492	54.8 58.5	274	64.3	173	54.2	41	31.8	63	7.0 5.1	35	8.2	20	6.3	7	5.4	12.8	36	7.3	5.5
Oscilloscope, multichannel 1983	321	35.7 38.9	200	46.9	91	28.5	23	17.8	38	4.2 3.3	27	6.3	9	2.8	1	0.8	11.8	17	5.3	6.5
Oscilloscope, plug-in modules 1983	278	31.0 30.9	167	39.2	90	28.2	18	14.0	32	3.6 3.4	22	5.2	7	2.2	2	1.6	11.5	21	7.6	4.0
Oscilloscope, portable 1983	304	33.9 34.8	184	43.2	92	28.8	20	15.5	41	4.6 4.2	29	6.8	9	2.8	2	1.6	13.5	15	4.9	8.6
Power supplies, dc, high voltage 1983	355	39.5 38.4	160	37.6	145	45.5	36	27.9	49	5.5 5.7	25	5.9	19	6.0	2	1.6	13.8	35	9.9	3.9
Power supplies, dc, low voltage 1983	573	63.8 63.3	307	72.1	198	62.1	55	42.6	88	9.8 8.2	49	11.5	31	9.7	6	4.7	15.4	68	11.9	3.5
Printer-plotter 1983	635	70.7 69.7	291	68.3	245	76.8	87	67.4	191	21.3 16.1	95	22.3	60	18.8	32	24.8	30.1	113	17.8	12.3
Recorder, oscillographic 1983	181	20.2 23.3	101	23.7	55	17.2	22	17.1	30	3.3 3.1	21	4.9	5	1.6	4	3.1	16.6	8	4.4	12.2
Thermometer, electronic digital 1983	379	42.2 45.0	204	47.9	133	41.7	32	24.8	96	10.7 9.6	50	11.7	29	9.1	12	9.3	25.3	45	11.9	13.5
Voltmeter, digital 1983	553	61.6 62.5	308	72.3	186	58.3	47	36.4	83	9.2 8.2	40	9.4	31	9.7	9	7.0	15.0	62	11.2	3.8
Waveform (transient) recorder 1983	111	12.4 12.0	63	14.8	38	11.9	7	5.4	48	5.3 4.7	31	7.3	13	4.1	3	2.3	43.2	10	9.0	34.2
Other 1983	51	5.7 6.1	26	6.1	16	5.0	7	5.4	28	3.1 3.3	15	3.5	9	2.8	4	3.1	54.9	15	29.4	25.5

OPINION POLL RESULTS

Republicans, political activism get vote in survey of readers

THE REPUBLICAN party has been the more responsive of the two major parties in the U.S. to the interests and needs of R&D. This is the conclusion to be drawn if our survey of nearly 1,800 readers is representative of the industry. Understandably, the respondents who rated Republicans as most responsive in the past expect that they would do better than the Democrats in the future.

In both instances, however, there was a large number (33% and 24%) rating the parties about equal.

Eighty-eight percent of the respondents believe that scientists and engineers should be involved, either as groups or as individuals, in politics as it affects R&D.

The complete results or our survey follow.

1. *Which major party has been the most responsive to R&D interests and needs?*
   a. Republican ... 41% c. About equal 33%
   b. Democrat 26

2. *Which of the major parties is most likely, in the next four years, to be responsive to R&D interests and needs?*
   a. Democrat ..... 28% c. About equal 24%
   b. Republican ... 48

3. *Political candidates often make promises in the heat of campaigning and then forget them. Which party has the best record for keeping its promises to R&D?*
   a. Republican ... 36% c. About equal 46%
   b. Democrat 18

4. *Do you think that scientists and engineers should be involved, either in groups or as individuals, in politics in general?*
   a. Yes ... 81% b. No ... 13% c. No opinion 6%

5. *Do you think that scientists and engineers should be involved, either in groups or as individuals, in politics as it affects R&D?*
   a. Yes ... 88% b. No .... 7% c. No opinion 4%

6. *Should well-known scientists and engineers identify with specific efforts to influence political decisions (including elections) favorably for R&D?*
   a. Yes ... 69% b. No ... 21% c. No opinion ... 10%

7. *Should scientists and engineers in general organize in order to bring pressure in support of candidates and ideas favorable to R&D?*
   a. Yes ... 64% b. No ... 26% c. No opinion ... 10%

8. *Do you consider yourself to be politically ...*
   a. Conservative 29% c. Middle of the road 23%
   b. Liberal ..... 14 d. Depends on the subject 34

9. *When it comes to elections, do you vote a "straight ticket" ...*
   a. Always ..... 2% d. Never 43%
   b. Usually ..... 20 e. Only to match President and Congress 2
   c. Not often 33

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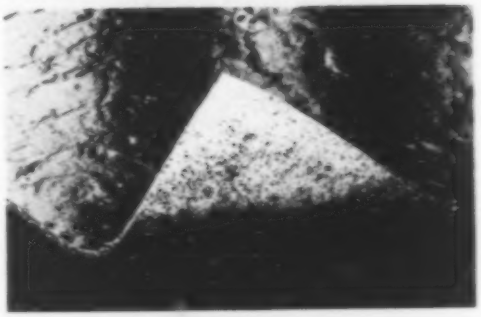

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Research & Development

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Research & Development

SERVING THE $202-BILLION WORLDWIDE R&D INDUSTRY

ABOUT THE COVER

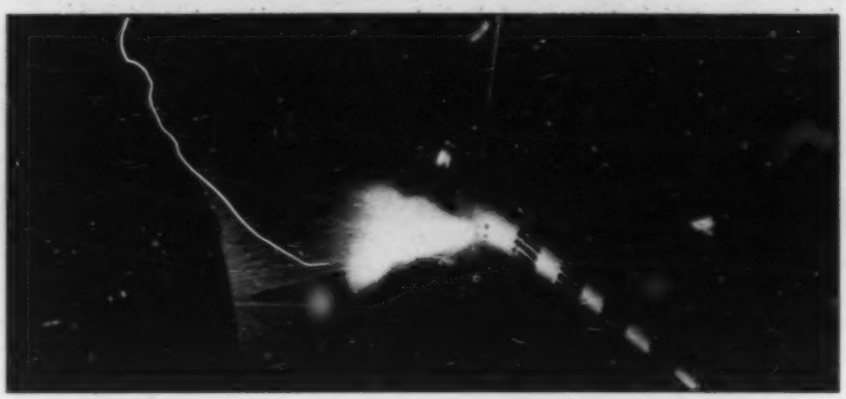
Laser comes of age

On May 15, 1960, Dr. Theodore H. Maiman unveiled the first working laser. Unlike many inventors, Maiman, presently a member of *R&D*'s Editorial Advisory Board, did foresee applications that only now, in this 25th anniversary year, are becoming realities.

For example, the fastest-growing application for General Laser Corp.'s line of axial-type CO_2 lasers is in metal cutting, as shown on the cover. Other large-scale applications are in welding and in heat-treating operations.

The laser fireworks at right appear in the laser-assisted machining of advanced alloys at General Electric's R&D Center. In attempts to improve productivity and to reduce costs in machining of titanium alloys, researchers are firing a YAG laser at rates as high as 300 pulses/sec. After this treatment, conventional tools can remove material at high operating speeds from the treated areas.

While the reputation of lasers' effectiveness has been based on exotic applications in medicine, electronics, and scientific research, the capabilities of lasers eventually will turn them into workhorses in numerous process applications.



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88 **For sensitive measurements, use a good electrometer:** Robert Green, Keithley Instruments; sensitivity for measuring high voltages at low current and high impedance.

96 **Find all the patents with full-text, on-line data base:** Jack W. Simpson, Mead Data Central; Boolean logic associates ideas.

102 **On-board processor lets A/D work directly with computer memory:** A.W. Davis, Data Translation; new software lets A/D converters work with lab microcomputers.

107 **Etched trenches conserve semiconductor device space:** D. Wang and J. Wong, Applied Materials; high-aspect-ratio etching makes buried capacitors practical.

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R&D funding will rise to $110 billion in 1985

Our annual forecast finds planned funding going up by 13.4% overall. Federal funding increase leads the way, but industry still is major source of dollars.

C.J. Mosbacher
Executive editor, *R&D*

NO RECESSION FOR R&D. That's the 1985 scenario based on the studies leading to our forecast of $110 billion total funding for this year.

Compare that to the total United States economy. The consensus of economic studies in late November called for real growth in the gross national product (GNP) of 3 to 5% in 1985. Inflation is expected to stay low at 4 to 5%. Thus total growth of 7 to 10% is foreseen in the year ahead, barring calamity.

But, again barring calamity and using a revision of our 1984 forecast as a base, R&D funding should rise 13.4%. The implication is that the proportion of GNP spent on R&D will continue to increase, as it has each year since 1978. In 1984, 2.7% of GNP was spent on R&D in the United States.

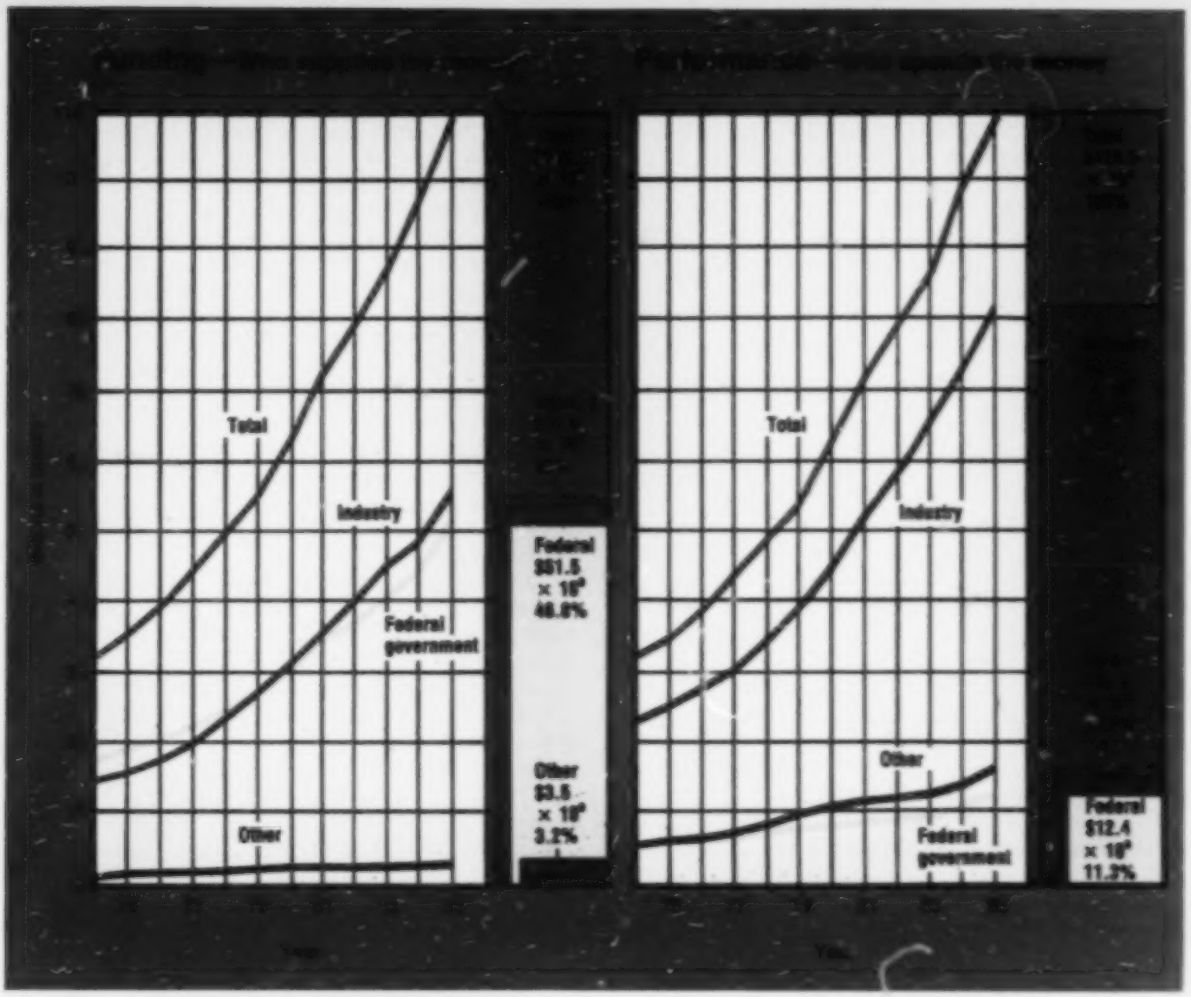
That percentage comes from "National patterns of science and technology resources 1984," NSF 84-311, the latest overall data on R&D funding from the National Science Foundation. While distributed last fall, its foreword is dated February 1984. According to this document, total R&D funds for 1984 were estimated at $96.975 billion, with the Federal government providing $44.270 billion, industry $49.375 billion, and universities and nonprofit organizations $3.330 billion.

The performance profile, or who spent these 1984 funds, is given as $10.800 billion in Federal government laboratories and R&D centers, $72.000 billion by industry in its own facilities, and $11.375 billion by universities and their associated research centers and $2.800 billion by other nonprofit institutions, giving a total of $14.175 billion.

NSF also estimated that 12% would be spent in 1984 on basic research, 22% on applied research, and 66% on development.

In our January 1984 forecast, we projected total funding for 1984 as $97.8 billion, with $50.5 billion provided by industry, $44.5 billion by the Federal government, and $2.8 billion by other sectors including academic and nonprofit organizations. Our performance projections were expenditures in industry of $73.9 billion, in Federal facilities of $10.5 billion, and in other sectors of $13.4 billion.

In addition to NSF 84-311, we also considered later data in revising our 1984 forecast to provide a basis for this 1985 forecast. We checked changes in Federal funding as monies appropriated by the Congress were obligated to specific projects and then were actually spent. We monitored changes in plans made by industry as revealed in financial reports and other documents and in conversations with executives in a number of companies. And we also monitored and checked leaders in academic and other nonprofit organizations. These procedures lead not only to the revised 1984 base but also give insights that aid our forecast.



Our revised base for 1984 gives a total of $97.0 billion for R&D funding. Industry provided $49.0 billion, the Federal government $44.7 billion, and other sectors $3.3 billion. Thus industry provided 50.5% of 1984 funds, the Federal government 46.1%, and other sectors 3.4%.

Revised performance data for 1984 are $72.0 billion for industry, $10.8 billion for Federal facilities, and $14.2 billion for other sectors. Thus industry spent 74.2% of available funds, Federal facilities 11.1%, and other sectors 14.6%.

While the revision in total funds is less than 1%, changes in the categories range from 2.5% to more than 21% in the smaller funding and performance levels for the academic and nonprofit sectors. What caused these changes from our earlier view and how we arrived at the sector levels of expenditures and performance forecast for 1985 that are shown graphically at the beginning of this article will be discussed sector by sector in the following paragraphs.

Incidentally, had we not revised our 1984 data, we would show a 12.47% increase in 1985 funding.

Industry spreads its support

By last June, NSF had received replies from 87 companies representing an estimated 53% of all R&D industrial funding in the United States. Projections based on data received were $49 billion of company funds to be spent in 1984 and $55 billion in 1985. (These data are reported in "Science resources studies highlights," NSF 84-329.)

Our discussions with executives in a somewhat smaller group of companies chosen to balance those that fund R&D cyclically with the economy against the countercyclical segment provided similar data—so close, in fact, that our industry figures round to the same as NSF's. An increase of 12.3% in funding and 12.8% in expenditure levels from 1984 to 1985 is indicated.

However, that does not mean that industry is putting more funds into its own facilities than into other sectors. The opposite is true. Late in 1983 the law was changed to remove major restrictions on cooperative R&D, allowing industry to form such new groups as the Semiconductor Research Foundation. This change also allowed nonprofit organizations such as Battelle to seek wider support for cooperative projects.

Industry also is expanding its funding of R&D in the academic area, continuing a trend from 1983.

NSF 84-329 also provides breakdowns of company funds to be spent in 1984 and 1985. For 1985, chemicals and allied products account for $9 billion, machinery (including computers) $10 billion, electrical equipment $11 billion, motor vehicles and their equipment $6 bil-

lion, aircraft and missiles $5 billion, professional and scientific instruments $5 billion, and all other segments $9 billion.

For 1984, the comparable estimates are, in billions, $8, $9, $10, $5, $4, $4, and $9. The largest increase, 17%, is in the professional and scientific instruments sector.

To summarize, we expect industry funding to rise from $49 billion in 1984 to $55 billion in 1985, with industry providing 50% of all R&D funds in 1985. Industry performance will rise from $72.0 billion to $81.2 billion so that industry will spend 73.8% of all R&D funds in 1985, down slightly from 74.2% in 1984.

Federal funding up significantly

Our forecast is that actual Federal funding for 1985 will increase 15.2% from 1984 to $51.5 billion. Performance in Federal facilities will rise 14.8% to $12.4 billion.

Such a large increase was not evident early last fall as the Congress and the Administration battled over acceptable levels for appropriations. NSF was the beneficiary of an early budget decision and appropriation with a significant increase. The National Institutes of Health benefitted from an appropriations bill that significantly increased funding, primarily because a companion piece of legislation provided for expansion of the number of NIH institutes. While President Reagan vetoed the expansion, he approved the appropriations measure, thus giving NIH more money for grants and other programs. For example, money for AIDs research was increased significantly.

But most government funding was provided by an omnibus appropriations bill at the last minute that gave the Administration much of what it had asked for in its original requests for R&D funding, plus additional amounts that the Congress tacked on. Thus a more than 20% increase in Dept. of Defense-sponsored R&D survived, for example.

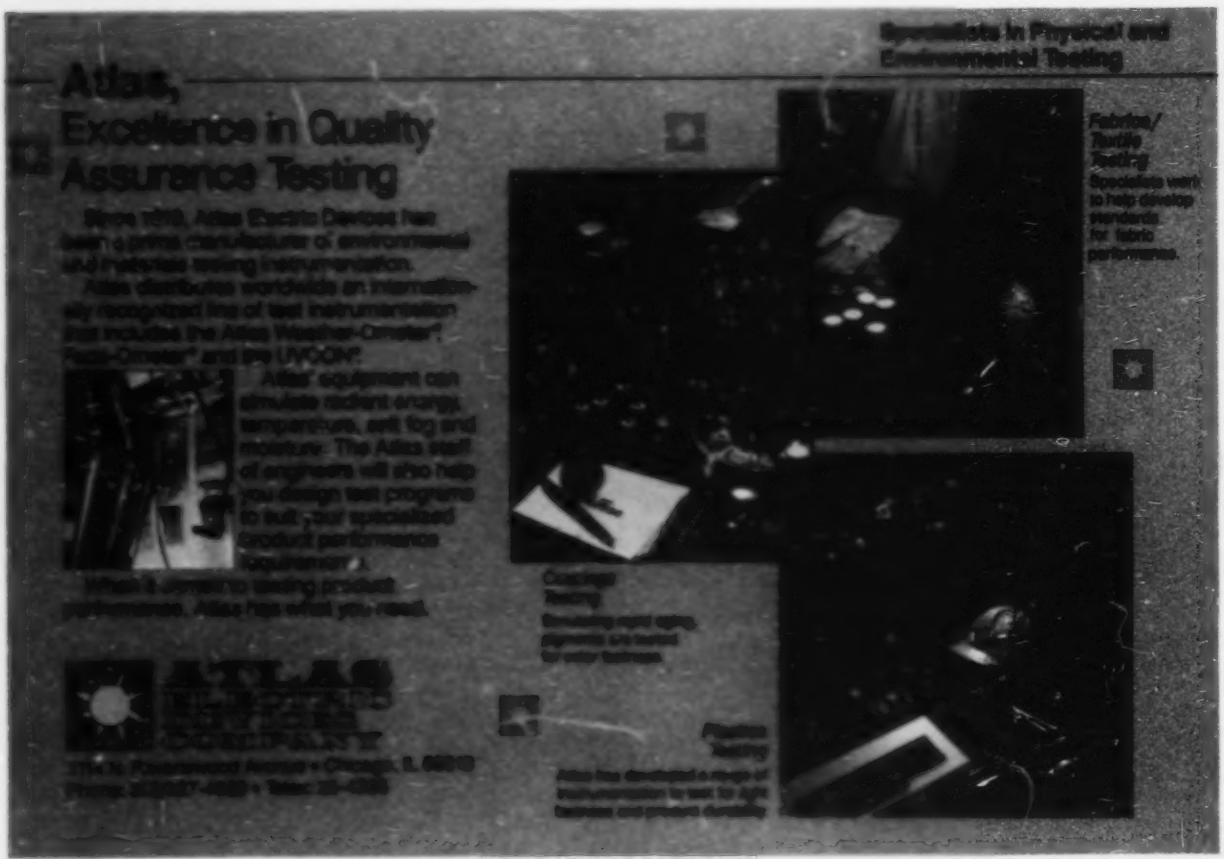
Thus, the Federal government will account for 46.8% of total funding in 1985, somewhat more than the 46.1% in 1984. In performance, the Federal share of the total rises from 11.1% to 11.3%.

Universities and nonprofits gain

Funds provided by other sectors rise only 6.1%, from $3.3 billion in 1984 to $3.5 billion in 1985. However, performance in these sectors really jumps, from $14.2 billion in 1984 to $16.4 billion in 1985. That is a 15.4% increase, leading to these sectors rising to 14.9% of performance in 1985 from 14.6% in 1984 while their actual contributions fall from 3.4% to 3.2% of total funding.

As noted earlier in the industry section, transfers of funds to cooperative R&D projects are creating more activity in the academic and nonprofit sectors. When Federal funding increases are added, the effect is a significant jump in performance levels.

The overall result? No recession for R&D. It would take a significant slowdown in industrial activity coupled with a virtual elimination of R&D funding by the Federal government in its fiscal 1986 budget to make R&D funds decrease in 1985. The probability of that, in our opinion, is zero. R&D



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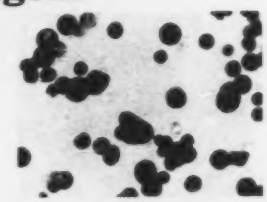

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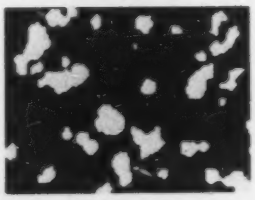

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OPINION POLL RESULTS

Pollution problems decline, aided by R&D staff efforts

POLLUTION is less severe in many parts of the world than it was in 1977, according to the nearly 2,000 respondents to our recent Opinion Poll survey on this subject. Currently, 24% believe that air pollution is fairly bad or severe in and near where they work, compared to 36% in 1977.

And, as might be expected, in many plants and institutions, it is the R&D people who are asked most often to help control pollution problems.

Some comparisons with 1977 and complete results of the current survey are shown below.

1. How severe is air pollution in and near where you work?

	1984	1977		1984	1977
a. Serious	6%	12%	c. Not very bad	50%	42%
b. Fairly bad	18	24	d. Hardly any	26	22

2. How severe is water pollution in and near where you work?

a. Serious	6%	9%	c. Not very bad	51%	46%
b. Fairly bad	24	30	d. Hardly any	19	15

3. How severe is noise pollution in and near where you work?

a. Serious	4%	7%	c. Not very bad	47%	48%
b. Fairly bad	20	22	d. Hardly any	29	23

4. Are you personally involved in pollution research or control?

a. Yes ..... 27% b. No* 73%

*(If no, please skip to question No. 9.)

5. In which of the following pollution research or control areas are you involved?

a. Water	34%	c. Noise	3%
b. Air	15	d. More than one	48

6. Do you work for . . .

a. Pollution control dept.	9%	d. Safety dept.	2%
b. Plant engineer	4	e. Quality control	9
c. R&D staff	43	f. Outside consultant	10
		g. Other	23

7. Which of the following items do you use in pollution control work?

a. Analyzing/testing instruments	9%
b. Monitoring instruments	3
c. Chemicals and materials	5
d. Control instruments	1
e. Some of the above	44
f. All of the above	34
g. None of the above	4

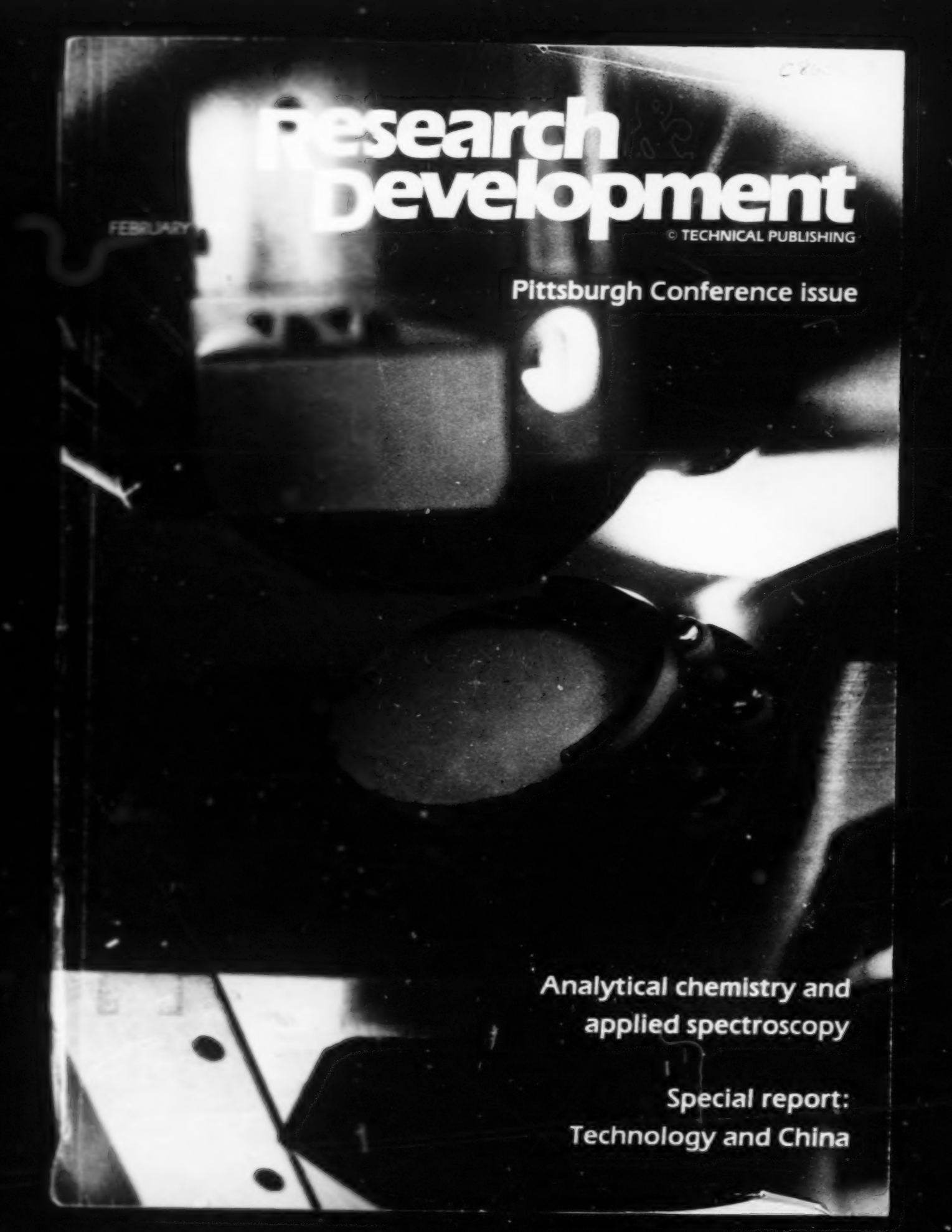
8. Do you get pollution control information primarily from . . .

a. Short courses	5%	c. Trade journals	53%
b. Conferences	10	d. Other	32

9. Does your company or organization have air, water, or noise pollution problems that, if not attended to, would become nuisances?

a. Yes . . . 50% b. No . . . 34% c. Don't know . . . 16%

CIRCLE 256 ON INQUIRY CARD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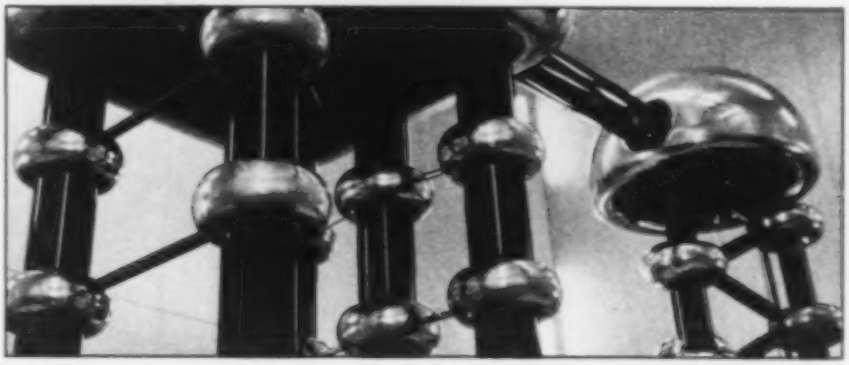
Research & Development

SERVING THE $202-BILLION WORLDWIDE R&D INDUSTRY

Pre-accelerator for an energy-saver ring. See p 136.



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ABOUT THE COVER

Recent advances in ESCA instrumentation provide high angular resolution and high count rates at low takeoff angles. These advances permit profiling through thin layers near the surface of a specimen.

Thus, variable-angle ESCA analysis permits probing of atomic layers on surfaces and at grain boundaries and interfaces. The cover picture, from PHI Perkin-Elmer, shows a phosphor being irradiated by an *x*-ray source in an ESCA instrument.

A related article begins on p 144, and another spectroscopy article begins on p 150. Articles on the Pittsburgh Conference and on analytical instrument trends begin on pp 157 and 174.

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Special Report—Technology and China

119 China's efforts to modernize mean more than just acquiring Western technology—they are causing serious concern for U.S. security interests, raising new questions about technology export control, and forcing a review of Chinese science institutions, and, the movement faces its biggest challenge from within Chinese society while the PRC government honors its first millionaire

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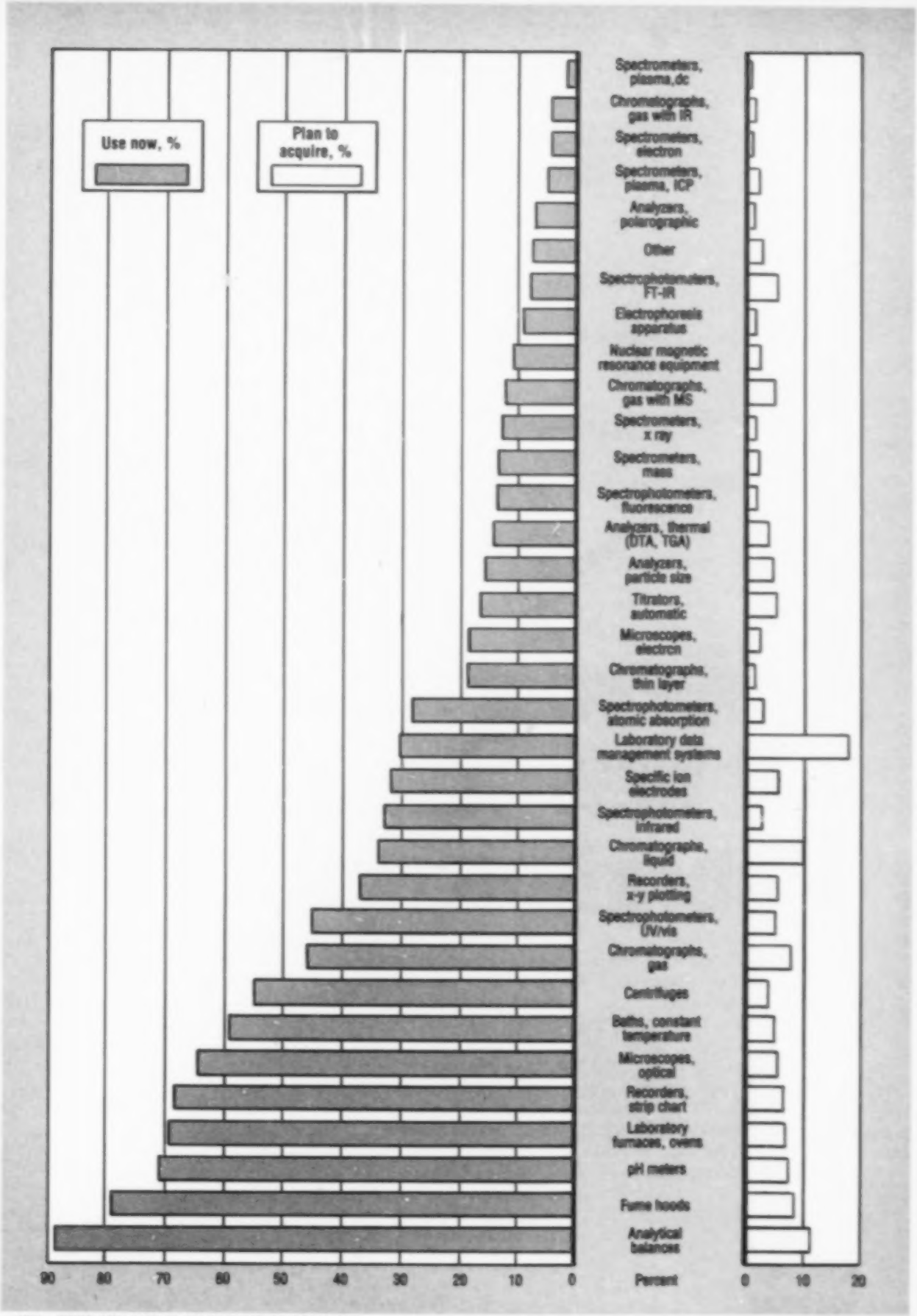

Use now, %
Plan to acquire, %
Spectrometers, plasma, dc
Chromatographs, gas with IR
Spectrometers, electron
Spectrometers, plasma, ICP
Analyzers, polarographic
Other
Spectrophotometers, FT-IR
Electrophoresis apparatus
Nuclear magnetic resonance equipment
Chromatographs, gas with MS
Spectrometers, x ray
Spectrometers, mass
Spectrophotometers, fluorescence
Analyzers, thermal (DTA, TGA)
Analyzers, particle size
Titrators, automatic
Microscopes, electron
Chromatographs, thin layer
Spectrophotometers, atomic absorption
Laboratory data management systems
Specific ion electrodes
Spectrophotometers, infrared
Chromatographs, liquid
Recorders, x-y plotting
Spectrophotometers, UV/vis
Chromatographs, gas
Centrifuges
Baths, constant temperature
Microscopes, optical
Recorders, strip chart
Laboratory furnaces, ovens
pH meters
Fume hoods
Analytical balances
90
80
70
60
50
40
30
20
10
0
Percent
0
10
20

C.J. Mosbacher
Executive editor, *R&D*

TRENDSURVEY

Use of analytical instruments and equipment, 1985

Average plans to acquire the 33 types of instruments listed in our annual survey increase more than 3% from last year, even after adjustments for demographics.

NO MATTER how you look at it, scientists and engineers are planning to acquire more analytical instruments and equipment in 1985 than they did in 1984. Yes, our latest annual Trendsurvey shows decreases in plans to acquire some instrument types, 9 to be exact, but their plans to acquire 20 types increase while plans for 4 types stay the same.

Looked at another way, plans to acquire average 5.13%, up significantly from the 1984 figure of 4.97%. Even after normalization to account for changes in the demographics or respondents, plans to acquire for 1985 actually increase slightly, to 5.14%. Average present use, which was 31.7% last year, drops less than 1.4% to 31.3% before normalization, which is 31.2% after normalizing.

For present use, 12 categories are up, 2 are equal, and 19 are lower than last year. The biggest gain was achieved by gas chromatographs, followed by liquid chromatographs, atomic absorption spectrophotometers, infrared spectrophotometers, laboratory data management systems, and FT-IR spectrophotometers. The biggest loss of present use was for laboratory furnaces and ovens, followed by strip-chart records, optical microscopes, electrophoresis apparatus, and mass spectrometers.

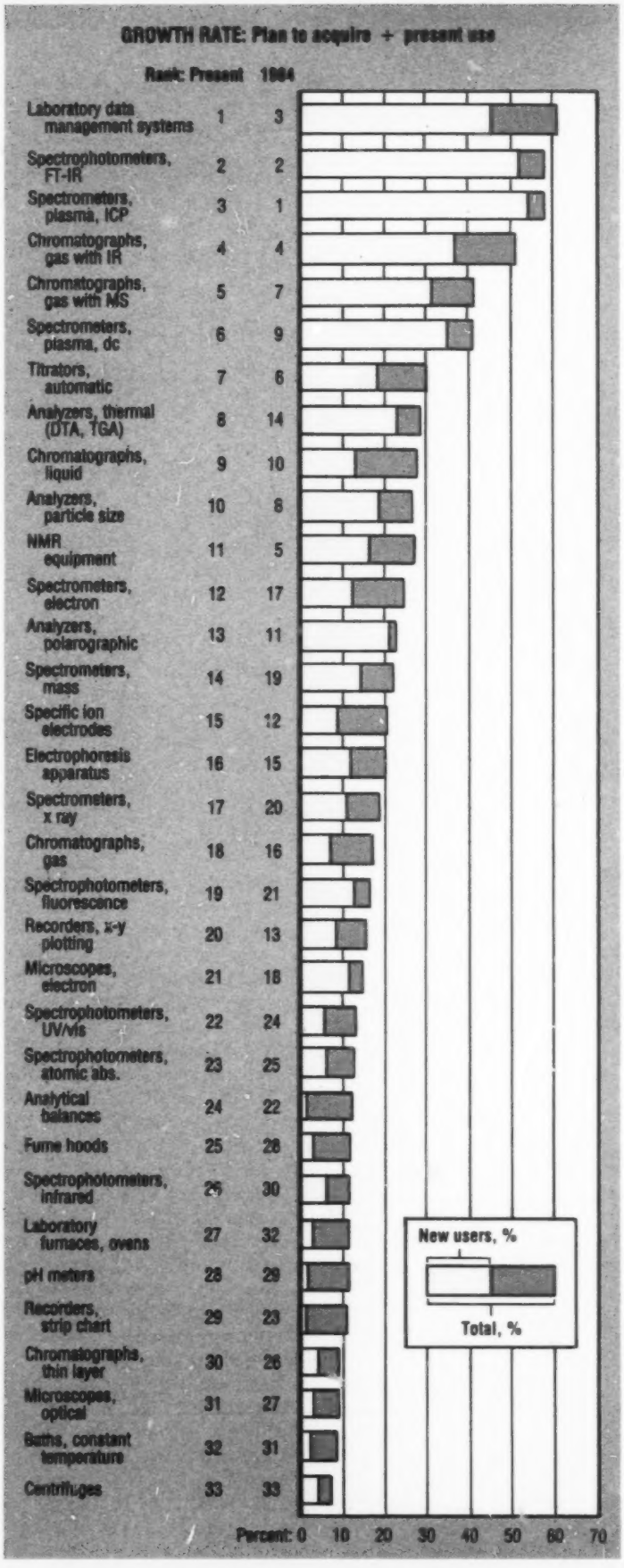
Largest gain of the 20 categories with increased plans to acquire was achieved by 2 categories, GC-MS and liquid chromatographs. Next largest, in order, were laboratory furnaces and ovens, laboratory data management systems, thermal analyzers, and UV/vis spectrophotometers.

The largest loss in plans to acquire was for x-y plotting recorders, followed by strip-chart recorders, optical microscopes, specific ion electrodes, and electron microscopes.

Ranking by present use is shown in the first bar chart for all 33 categories and "other" on a total-sample basis. On that same basis, rankings for plans to acquire are led by laboratory data management systems, followed by analytical balances, liquid chromatographs, fume hoods, and gas chromatographs. Last year, strip-chart recorders occupied third place, and fume hoods were sixth.

Rankings by growth rate (plans to acquire divided by present use for each category) are shown in the second bar chart. Laboratory data management systems rank first on this basis also, although other categories now occupy the remaining top spots. Rankings for last year also are shown on the chart. The differences between using the total sample versus the present use as a base for calculating growth or growth rate are well illustrated by this comparison of rankings.

Gains in these rankings were lead by thermal analyzers, up six places from last year. Laboratory furnaces and ovens and electron spectrometers each are up five places, with infrared spectrophotometers up four places (FT-IR, incidentally, held second place). Biggest loser in the rankings were x-y plotting recorders, which dropped seven places in the rankings, followed by NMR equipment and strip-chart recorders,


GROWTH RATE: Plan to acquire + present use
Rank: Present 1984
Laboratory data management systems 1 3
Spectrophotometers, FT-IR 2 2
Spectrometers, plasma, ICP 3 1
Chromatographs, gas with IR 4 4
Chromatographs, gas with MS 5 7
Spectrometers, plasma, dc 6 9
Titrators, automatic 7 6
Analyzers, thermal (DTA, TGA) 8 14
Chromatographs, liquid 9 10
Analyzers, particle size 10 8
NMR equipment 11 5
Spectrometers, electron 12 17
Analyzers, polarographic 13 11
Spectrometers, mass 14 19
Specific ion electrodes 15 12
Electrophoresis apparatus 16 15
Spectrometers, x ray 17 20
Chromatographs, gas 18 16
Spectrophotometers, fluorescence 19 21
Recorders, x-y plotting 20 13
Microscopes, electron 21 18
Spectrophotometers, UV/vis 22 24
Spectrophotometers, atomic abs. 23 25
Analytical balances 24 22
Fume hoods 25 28
Spectrophotometers, infrared 26 30
Laboratory furnaces, ovens 27 32
pH meters 28 29
Recorders, strip chart 29 23
Chromatographs, thin layer 30 26
Microscopes, optical 31 27
Baths, constant temperature 32 31
Centrifuges 33 33
New users, %
Total, %
Percent: 0 10 20 30 40 50 60 70

each losing six places. Thin-layer chromatographs and optical microscopes each lost four places in these rankings by growth rate.

Before turning to demographics, another indication of the reality of increased plans to acquire is given by changes in the percentages of those not giving any answers for present use and plans to acquire. In the present Trendsurvery, 2.1% did not indicate present use of any instrument, compared to 1.0% last year. Conversely, for plans to acquire, "no" answers dropped to 39.4% from 41.0% in last year's results.

As for demographics, geographic distribution of respondents again parallels the circulation of *R&D*, lending validity to the results because that circulation is kept in proportion to distribution of funds and personnel in the field. New England accounts for 6.9% of respondents to the Trendsurvey, Middle Atlantic 17.8, East North Central 19.5, West North Central 6.2, South Atlantic 14.0, East South Central 4.0, West South Central 7.5, Mountain 4.8, and Pacific 11.9.

By discipline, 20.7% list engineering, 56.9 physical science, 19.6 life science or medicine, while 2.9 gave no answer. For last year's survey, the comparable data were 23.3% engineering, 53.6 physical science, 20.2 life science or medicine, and 2.9 no answer. Thus there has been a shift of 3.3 points, or 7.4%, to the physical sciences from the other categories.

By employer, 59.2% work in industry, 14.1 in universities, 16.0 in government, 3.1 in nonprofit organizations, 2.4 in medical research centers, 4.0 other, and 1.2 no answer. Corresponding data for last year were 57.7% industry, 16.0 universities, 15.5 government, 3.8 nonprofit, 2.3 medical research, 3.3 other, and 1.3 no answer.

By job function, 4.0% are corporate officers, 8.2 R&D executives, 13.6 project managers, 67.2 professional staff, 5.0 other, and 1.8 no answer. This is a shift of almost 6.9% from management to staff positions from last year, when the corresponding figures were 4.2% corporate officers, 7.7 R&D executives, 15.8 project managers, 66.5 professional staff, 4.3 other, and 1.6 no answer.

This Trendsurvey was conducted by including a prepaid business reply card in a mailing to *R&D* readers in the United States in late September 1984. To meet deadlines, only replies received by early November could be included in the data here. R&D

GROWTH RATE (bar chart at left) is calculated with present use as base for each instrument category. Total includes all those who plan to acquire; new users are those who do not presently use that instrument but who plan to acquire. Difference is present users planning to acquire additional or replacement units in that particular instrument category.

PRESENT AND PLANNED USE: Data from 1,261 respondents * = 1984	Use now								Plan to acquire within 1 yr								Growth rate = plan to acquire + by present use				
	Total 1,261		Engineering 261		Physical science 717		Life science or medicine 247		Total 1,261		Engineering 261		Physical science 717		Life science or medicine 247		Total	Present users who plan to acquire		New users	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	%	No.	%	No.	%
Analytical balances	1,129	89.5 *88.4	201	77.0	664	92.6	200	93.1	135	10.7 *10.6	20	7.7	94	13.1	20	8.1	12.0	116	10.3	19	1.7
Analyzers, particle size	206	16.3 *17.9	47	18.0	124	17.3	28	11.3	59	4.7 * 4.8	15	5.7	38	5.3	5	2.0	28.6	19	9.2	40	19.4
Analyzers, polarographic	89	7.1 * 6.0	11	4.2	62	8.6	12	4.9	20	1.6 * 1.4	6	2.3	13	1.8	1	0.4	22.5	1	1.1	19	21.3
Analyzers, thermal (DTA, TGA)	177	14.0 *15.9	42	16.1	115	16.0	15	6.1	53	4.2 * 3.3	9	3.4	39	5.4	3	1.2	29.9	11	6.2	42	23.7
Baths, constant temperature	747	59.2 *61.5	110	42.1	425	59.3	192	77.7	67	5.3 * 5.8	15	5.7	40	5.6	12	4.9	9.0	45	6.0	22	2.9
Centrifuges	692	54.9 *55.1	71	27.2	339	54.3	209	84.6	53	4.2 * 4.4	8	3.1	26	3.6	17	6.9	7.7	27	3.9	26	3.8
Chromatographs, gas	585	46.4 *43.9	69	26.4	408	56.9	87	35.2	108	8.6 * 8.2	9	3.4	81	11.3	16	6.5	18.5	67	11.5	41	7.0
Chromatographs, gas with IR	55	4.4 * 4.9	13	5.0	33	4.6	5	2.0	28	2.2 * 2.0	3	1.1	23	3.2	1	0.4	50.9	7	12.7	21	38.2
Chromatographs, gas with MS	148	11.7 *11.8	13	5.0	114	15.9	15	6.1	62	4.9 * 3.2	3	1.1	43	6.0	12	4.9	41.9	15	10.1	47	31.8
Chromatographs, liquid	429	34.0 *31.6	31	11.9	278	38.8	105	42.5	126	10.0 * 8.3	9	3.4	88	12.3	28	11.3	29.4	71	16.6	55	12.8
Chromatographs, thin layer	244	19.3 *19.7	12	4.6	154	21.5	72	29.1	24	1.9 * 2.1	2	0.8	16	2.2	5	2.0	9.8	14	5.7	10	4.1
Electrophoresis apparatus	124	9.8 *12.5	6	2.3	37	5.2	78	31.6	25	2.0 * 2.4	2	0.8	13	1.8	10	4.0	20.2	9	7.3	16	12.9
Fume hoods	1,000	79.3 *80.2	178	68.2	592	82.6	202	81.8	111	8.8 * 8.2	30	11.5	63	8.8	15	6.1	11.1	78	7.8	33	3.3
Laboratory data mngmt. systems	380	30.1 *28.4	58	22.2	234	32.6	79	32.0	232	18.4 *17.3	47	18.0	141	19.7	38	15.4	61.1	59	15.5	173	45.5
Laboratory furnaces, ovens	881	69.9 *76.2	177	67.8	537	74.9	137	55.5	94	7.5 * 6.1	29	11.1	54	7.5	9	3.6	10.7	67	7.6	27	3.1
Microscopes, electron	239	19.0 *19.7	67	25.7	116	16.2	47	19.0	36	2.9 * 3.6	10	3.8	21	2.9	5	2.0	15.1	10	4.2	26	10.9
Microscopes, optical	818	64.9 *68.0	170	65.1	447	62.3	179	72.5	75	5.9 * 7.0	23	8.8	35	4.9	14	5.7	9.2	48	5.9	27	3.3
Nuclear magnetic resonance eqpmt.	127	10.1 * 9.5	12	4.6	100	13.9	11	4.5	36	2.9 * 2.9	4	1.5	22	3.1	9	3.6	28.3	12	9.4	24	18.9
pH meters	904	71.7 *71.4	127	48.7	527	73.5	221	89.5	97	7.7 * 7.0	18	6.9	59	8.2	16	6.5	10.7	76	8.4	21	2.3
Recorders, strip chart	869	68.9 *72.5	177	67.8	508	70.9	161	65.2	91	7.2 * 8.6	24	9.2	52	7.3	14	5.7	10.5	75	8.6	16	1.8
Recorders, x-y plotting	476	37.7 *37.7	127	48.7	258	36.0	78	31.6	74	5.9 * 7.9	29	11.1	34	4.7	11	4.5	15.5	31	6.5	43	9.0
Specific ion electrodes	400	31.7 *32.0	46	17.6	273	38.1	67	27.1	81	6.4 * 7.3	13	5.0	50	7.0	15	6.1	20.3	44	11.0	37	9.2
Spectrometers, electron	56	4.4 *4.4	15	5.7	31	4.3	9	3.6	15	1.2 * 0.8	4	1.5	9	1.3	2	0.8	26.8	8	14.3	7	12.5
Spectrometers, mass	164	13.0 *15.7	26	10.0	118	16.5	16	6.5	36	2.9 * 2.6	8	3.1	24	3.3	4	1.6	22.0	13	7.9	23	14.0
Spectrometers, plasma, dc	17	1.3 * 2.4	2	0.8	11	1.5	3	1.2	7	0.6 * 0.6	3	1.1	4	0.6	—	—	41.2	1	5.9	6	35.3
Spectrometers, plasma, ICP	61	4.8 * 3.7	11	4.2	45	6.3	3	1.2	36	2.9 * 2.7	2	0.8	28	3.9	2	0.8	59.0	3	4.9	33	54.1
Spectrometers, x ray	153	12.1 *13.6	30	11.5	106	14.8	12	4.9	29	2.3 * 2.1	7	2.7	18	2.5	4	1.6	19.0	10	6.5	19	12.4
Spectrophotometers, atomic abs.	348	27.6 *25.3	40	15.3	247	34.4	51	20.6	43	3.4 * 2.7	6	2.3	33	4.6	3	1.2	12.4	20	5.7	23	6.6
Spectrophotometers, fluorescence	166	13.2 *13.5	16	6.1	86	12.0	39	23.9	30	2.4 * 2.0	3	1.1	15	2.1	12	4.9	18.1	7	4.2	23	13.9
Spectrophotometers, FT-IR	108	8.6 * 7.1	16	6.1	79	11.0	8	3.2	64	5.1 * 4.7	10	3.8	51	7.1	1	0.4	59.3	7	6.5	57	52.8
Spectrophotometers, infrared	424	33.6 *31.5	48	18.4	323	45.0	38	15.4	46	3.6 * 3.1	9	3.4	30	4.2	7	2.8	10.8	21	5.0	25	5.9
Spectrophotometers, UV/vis	571	45.3 *44.5	49	18.8	366	51.0	141	57.1	72	5.7 * 4.9	8	3.1	46	6.4	16	6.5	12.6	39	6.8	33	5.8
Titrators, automatic	221	17.5 *18.0	21	8.0	166	23.2	27	10.9	67	5.3 * 5.3	10	3.8	45	6.3	10	4.0	30.3	24	10.9	43	19.5
Other	98	7.8 * 8.2	23	8.8	54	7.5	19	7.7	44	3.5 * 3.8	9	3.4	26	3.6	7	2.8	44.9	22	22.4	22	22.4

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Research & Development

MARCH 1985

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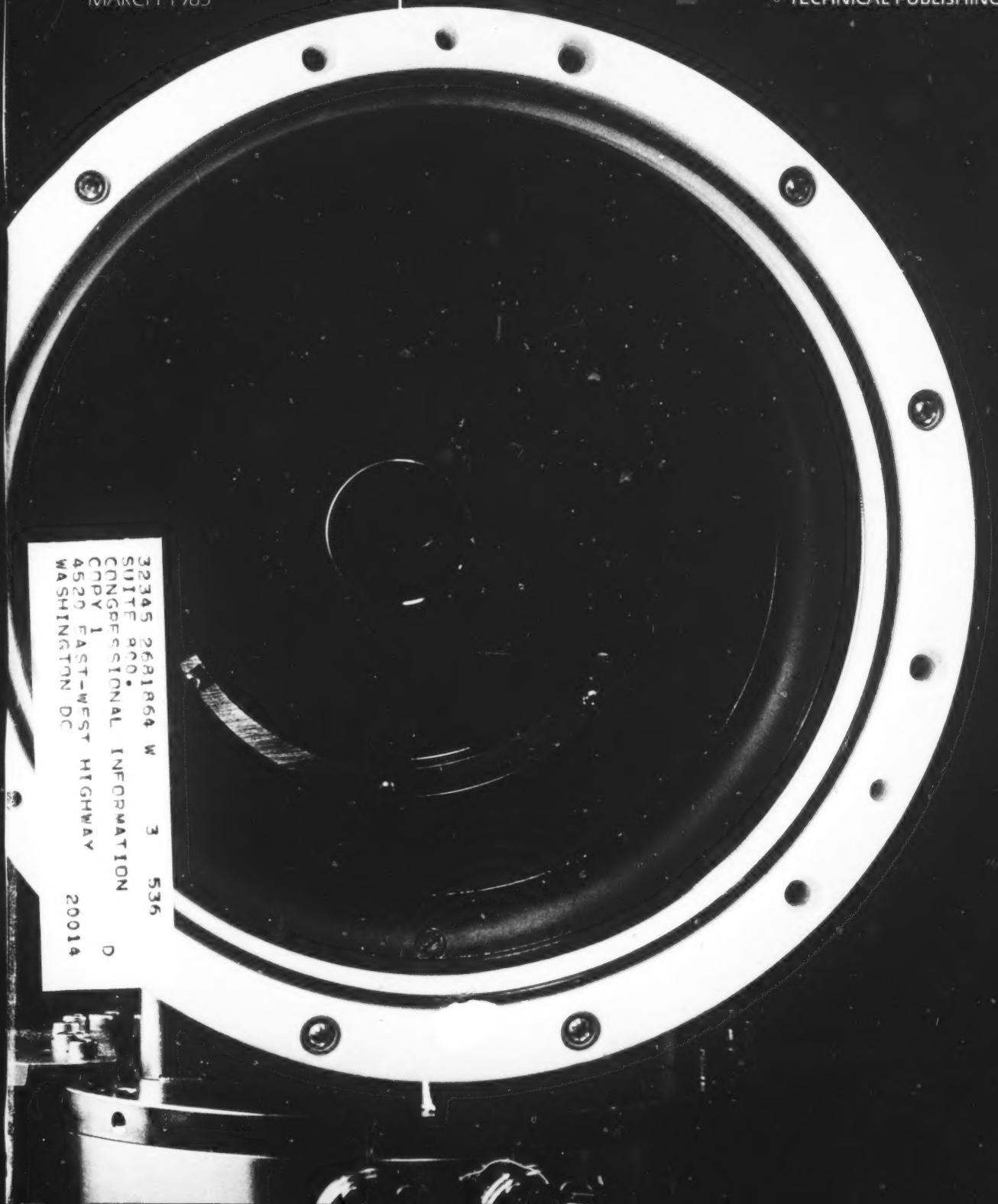

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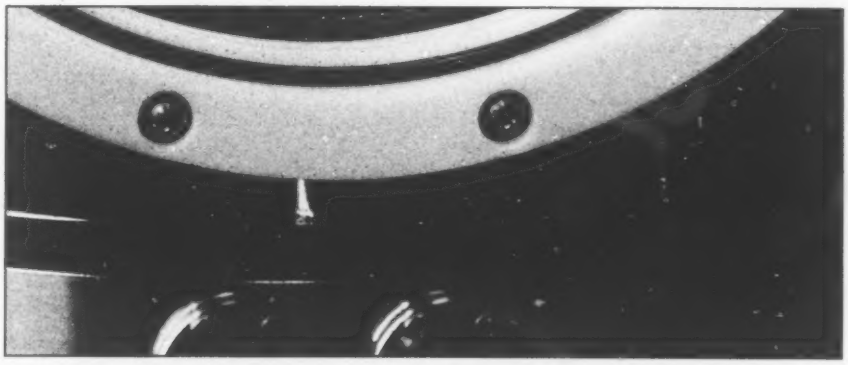
Research & Development

SERVING THE $202-BILLION WORLDWIDE R&D INDUSTRY

Better magnetic storage disks. See p 111.



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ABOUT THE COVER

Increasing the amount of information that can be magnetically stored per in.^{2} of media is of primary importance to the computer industry. A large part of this technology depends on how well the magnetic material is sputtered onto the substrate. To meet an industry need for a reliable production system, R&D scientists at Varian Associates Inc., Palo Alto, CA, developed the MDP-1000 disk sputtering system.

Maximum system throughput is 180 disks/hr. Each disk is treated individually in up to six separate process chambers, one of which is shown in the cover image. The system is described in detail in an article that begins on p 111.

Cover photo for this issue by Peter Nuding Photography.

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1984 was a good year for R&D salaries

Pay increases, mainly in the 2- to 9%-range, with inflation near 4%, bring substantial buying power gains to applied scientists whose U.S. incomes now exceed $24 billion.

Robert R. Jones, Editor

YOUR WALLET OR PURSE is a little bit heavier now than it was at this time a year ago if you are typical of the nearly 3,700 readers of this magazine who responded to our annual survey of the industry. Because salary increases substantially exceeded inflation for research and development scientists and engineers in the United States last year, you probably have a little something left at the end of each month—or you are enjoying an enhanced standard of living that the increased buying power has made possible in recent months.

As a generalization, this year's annual profile of our industry is more upbeat than several recent ones. In fact, it was an up year for R&D in a number of important ways.

The salary range continues to expand, as it has for several years, with the upper end climbing while the lower end remains essentially unchanged (putting the lie to a hint last year that the lower end had begun to climb).

One bit of explanation is necessary for those of our readers who have followed previous reports in detail or who plan to make comparisons with previous years. Our salary scale was established with $3,000 spans—$16,000 through $18,000, $19,000 through $21,000—in the years when our top income figure was below $50,000. As we added a span or two each year and reached the $70,000 level last year, the number of spans in our report became burdensome.

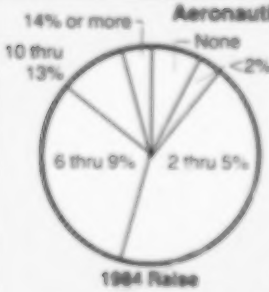
This year we made a break, albeit at the short-term cost of losing some direct comparisons that we have been making over the years. This year the spans cover $5,000, *e.g.*, $15,000 through $19,000. This will permit more-presentable charts and tables and, in a few years, a resumption of the annual direct comparisons of span to span. Even now, if you read on, you will see that a vast number of comparisons and correlations remains.

1.5% get more than $75,000

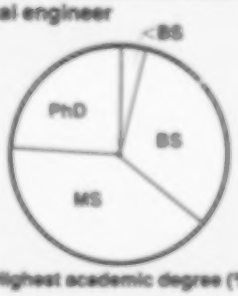
Where last year's lowest salary level surveyed was "less than $16,000," this year's was "less than $15,000." The portion of respondents in that bottom income level was the same as for last year's bottom level, 1.6%. And, as mentioned, the range expansion is upward, with the result that the new top level annual income of "$75,000 or more" is occupied by 1.5% of the respondents.

At the beginning of this decade, 4% of our respondents listed an annual salary of $46,000 a year or more. The most populous single salary span that year (1980) was $25,000 through $27,000. By last year, the portion

Aeronautical engineer



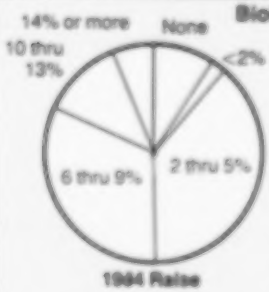
1984 Raise



Highest academic degree (%)

1984 salary range:	<$15,000 = 1.8% >$75,000 = 1.8	Median $49,330
Years with present employer:	< 1 yr = 3.6% >36 yr = 0.0	Median 15.95 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0	Median 50.92 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 5.4	Median 26.52 yr

Biologist

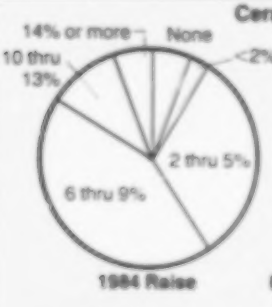


1984 Raise

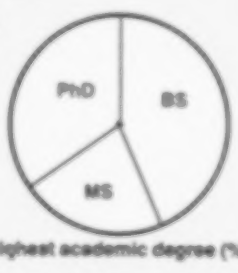
Highest academic degree (%)

1984 salary range:	<$15,000 = 1.8% >$75,000 = 0.4	Median $34,950
Years with present employer:	< 1 yr = 3.5% >36 yr = 0.4	Median 9.15 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 2.2	Median 39.80 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.9	Median 12.90 yr

Ceramist



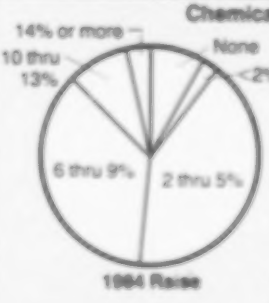
1984 Raise



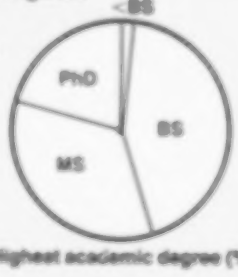
Highest academic degree (%)

1984 salary range:	<$15,000 = 0.0% >$75,000 = 3.1	Median $43,450
Years with present employer:	< 1 yr = 7.6% >36 yr = 1.5	Median 8.45 yr
Age of respondents:	<26 yr = 4.5% >65 yr = 1.5	Median 40.08 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0	Median 16.38 yr

Chemical engineer



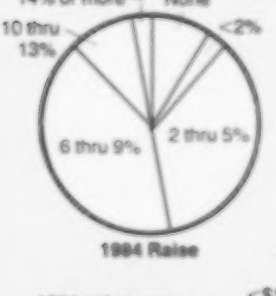
1984 Raise



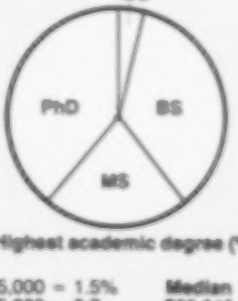
Highest academic degree (%)

1984 salary range:	<$15,000 = 1.6% >$75,000 = 1.2	Median $42,390
Years with present employer:	< 1 yr = 2.7% >36 yr = 2.3	Median 10.06 yr
Age of respondents:	<26 yr = 3.5% >65 yr = 1.6	Median 40.87 yr
Years of experience:	< 1 yr = 0.4% >40 yr = 1.6	Median 16.59 yr

Chemist



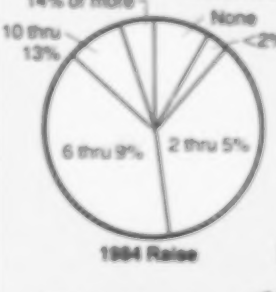
1984 Raise



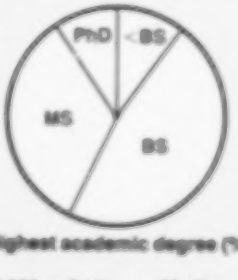
Highest academic degree (%)

1984 salary range:	<$15,000 = 1.5% >$75,000 = 0.7	Median $39,040
Years with present employer:	< 1 yr = 4.2% >36 yr = 1.1	Median 9.93 yr
Age of respondents:	<26 yr = 2.2% >65 yr = 1.2	Median 41.04 yr
Years of experience:	< 1 yr = 0.7% >40 yr = 1.8	Median 14.47 yr

Electrical engineer



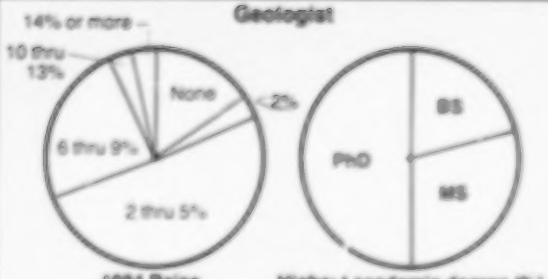
1984 Raise



Highest academic degree (%)

1984 salary range:	<$15,000 = 3.1% >$75,000 = 1.8	Median $42,910
Years with present employer:	< 1 yr = 4.3% >36 yr = 1.8	Median 11.01 yr
Age of respondents:	<26 yr = 2.8% >65 yr = 1.8	Median 45.39 yr
Years of experience:	< 1 yr = 0.6% >40 yr = 2.1	Median 21.72 yr

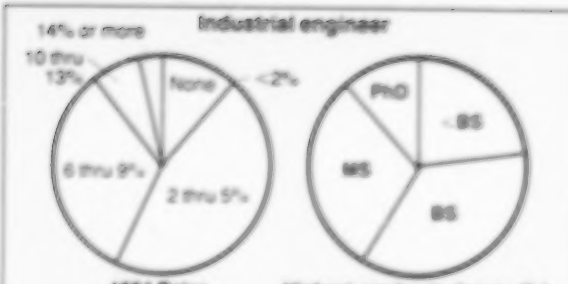
Geologist



1984 Raise — Highest academic degree (%)

1984 salary range:	<$15,000 = 5.4% >$75,000 = 7.1	Median $41,830
Years with present employer:	< 1 yr = 7.1% >36 yr = 1.8	Median 8.28 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0	Median 46.50 yr
Years of experience:	< 1 yr = 3.6% >40 yr = 1.8	Median 19.09 yr

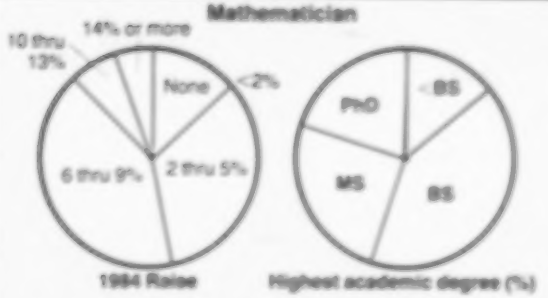
Industrial engineer



1984 Raise — Highest academic degree (%)

1984 salary range:	<$15,000 = 0.0% >$75,000 = 0.0	Median $38,280
Years with present employer:	< 1 yr = 7.1% >36 yr = 2.4	Median 10.70 yr
Age of respondents:	<26 yr = 2.4% >65 yr = 0.0	Median 47.64 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 4.9	Median 22.14 yr

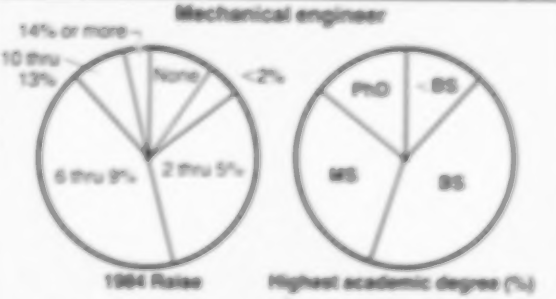
Mathematician



1984 Raise — Highest academic degree (%)

1984 salary range:	<$15,000 = 0.0% >$75,000 = 6.7%	Median $51,200
Years with present employer:	< 1 yr = 6.7% >36 yr = 0.0	Median 12.95 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 6.7	Median 48.00 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 13.3	Median 24.60 yr

Mechanical engineer



1984 Raise — Highest academic degree (%)

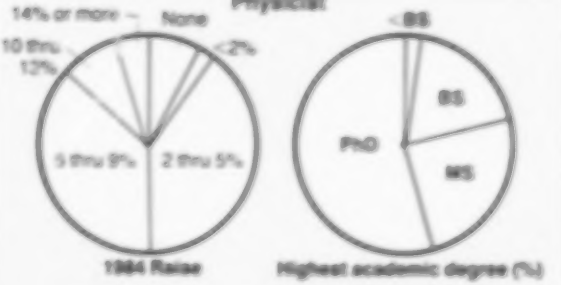
1984 salary range:	<$15,000 = 0.3% >$75,000 = 2.0	Median $42,160
Years with present employer:	< 1 yr = 2.6% >36 yr = 1.5	Median 10.05 yr
Age of respondents:	<26 yr = 2.3% >65 yr = 1.7	Median 44.45 yr
Years of experience:	< 1 yr = 0.6% >40 yr = 4.1	Median 18.70 yr

Metallurgist

1984 Raise — Highest academic degree (%)

1984 salary range:	<$15,000 = 1.1% >$75,000 = 2.6	Median $44,580
Years with present employer:	< 1 yr = 5.3% >36 yr = 0.0	Median 10.22 yr
Age of respondents:	<26 yr = 2.1% >65 yr = 1.1	Median 43.07 yr
Years of experience:	< 1 yr = 0.5% >40 yr = 1.1	Median 17.35 yr

Physicist



1984 Raise — Highest academic degree (%)

1984 salary range:	<$15,000 = 0.3% >$75,000 = 1.2	Median $43,120
Years with present employer:	< 1 yr = 7.0% >36 yr = 0.0	Median 10.62 yr
Age of respondents:	<26 yr = 1.2% >65 yr = 2.1	Median 43.56 yr
Years of experience:	< 1 yr = 0.9% >40 yr = 1.5	Median 17.42 yr

of respondents earning $46,000 or more was 25.1%, with the most populous span being $34,000 through $36,000.

Today, 35.1% of our respondents report annual salaries of $45,000 or more and the most populous span is $40,000 through $44,000, with 15.7% of the respondents occupying it.

Not too surprisingly, the median income for this year's respondents falls in that range at $40,180, up 6.3% from last year's $37,800. This rate of increase is close to 1981's and 1982's of 7.8% and 7.7%, but well above last year's increases (given in 1983) of 4.2%. More to the point is the fact that the 1984 increases that are in effect now follow low inflation rates, whereas the 1981 and 1982 increases followed much higher rates of inflation.

Industry payroll $24 billion

One result of these rising figures is that you are a member of an affluent demographic segment. Workers in research, development, and quality assurance in the United States will draw an annual paycheck in 1985 of $24.1 billion, up impressively from $18.9 billion in 1984.

It is needless to say that as a consequence of all of this, the median salary of R&D workers has moved up accordingly. Rather than just say it, let's set it out in the following table.

Increases in salary, all levels R&D

	% of respondents				
Amount	1985	1984	1983	1982	1981
None	9.3	10.3	14.7	6.3	5.2
Less than 2%	2.9	2.1	1.8	1.2	0.9
2 thru 5%	26.6	26.9	15.9	10.6	6.0
6 thru 9%	37.6	38.9	34.3	34.5	45.2
10 thru 13%	10.1	11.5	25.1	34.0	29.7
14% or more	3.6	4.4	8.3	13.3	11.0
Ahead of inflation	63.3	54.8	33.4	47.3	40.7

The table shows that buying power has increased for R&D workers as a group. Two out of every three workers did better than just stay even with inflation. This is true even though the percentages in the upper salary increase levels are much lower than they were in the early part of this decade. A much lower inflation level explains what at first appears to be contradictory.

The portion of respondents receiving no salary increase last year has dropped off sharply from preceding years, having climbed steadily from 5.2% in 1981's report to 16.3% in last year's. Now it is back down to 9.3% (including, of course, a substantial percentage of new hires).

The most impressive salary increase performance came from the ceramists with 60% getting raises of 6% or more last year. They were followed by mechanical engineers, mathematicians, and chemists (last year's leader), all closely bunched at 53.6%, 53.4%, and 52.7%. Geologists were at the low end of this group with 32.2% getting salary increases of 6% or more.

Details of this year's salary increases and those for five other salary parameters are displayed in charts for 12 disciplines accompanying this article. These charts present an opportunity for you to make comparisons by disciplines, education, age, experience, and longevity, using information that is available nowhere else.

Looking at median salaries by disciplines, mathematicians held onto first place with a 14.4% increase over last year. Aeronautical engineers and ceramists made strong gains. The smallest improvements in median salaries were recorded by biologists and geologists with both losing rank in the comparison table.

Rankings for disciplines by median salary

Rank			Median salary		
1985	1984	Discipline	1985	1984	% increase
1	1	Mathematician	$51,200	$44,750	14.4
2	2	Aero. Engr.	49,330	43,550	13.3
3	3	Metallurgist	44,580	41,310	7.9
4	9	Ceramist	43,450	39,200	10.0
5	5	Physicist	43,120	40,770	5.8
6	8	Elec. Engr	42,910	39,240	9.4
7	6	Chem. Engr.	42,390	40,140	5.6
8	7	Mech. Engr.	42,180	40,010	5.4
9	4	Geologist	41,830	40,950	2.1
10	10	Chemist	39,040	36,510	6.9
11	11	Indust. Engr.	38,280	36,280	5.5
12	13	Other	35,190	33,480	5.1
13	12	Biologist	34,950	33,660	3.8

There continues to be a premium on age, experience, and advanced degrees. As one result, the median age of respondents to our survey has moved steadily upward, with the median age in 1980 being 40.4 years, followed by 40.9, 40.9, 41.4, 41.5, and this year's 42.0.

Likewise, the median years of experience for our respondents has increased from 15.8 years in 1982 to this year's 16.5.

Dollars for experience

When salary is correlated to experience, this premium for experience becomes more obvious. For this year's respondents with less than a year's experience, the median income is $27,020. Median for those with one through five years is $30,380. For six through 10, it is $35,030, and so it goes to a median annual salary of $47,210 for those with more than 40 years' experience.

The percentage of respondents with PhD degrees has moved from 27.6 in 1980 with only one hesitation (in 1983) to its present 33.1%. Geologists no longer lead the disciplines in the percentage with a PhD, having been crowded out of first place by the physicists with 53.4%. Biologists are second with 51.8% followed by the formerly leading geologists at 50.0%.

There is a substantial gap from the geologists to the fourth-place discipline, chemists at 39.8%. They are followed by metallurgists at 37.6 and ceramists at 33.8. Electrical engineers have the lowest percentage of PhDs at 9.5.

When masters degrees and doctorates are considered together and the disciplines are ranked for advanced degrees, geologists lead with 78.6% having an advanced degree. Biologists are next at 78.1, followed by physicists, 77.6; metallurgists, 66.2; and aeronautical engineers, 62.5.

In the second part of this report, we will look into the implications of some of the above conclusions and also report on the value of an advanced degree to its holder, relative salary scales of men and women, and the advantages in salaries for jobs in industry, government, or university. R&D

Research Development

MAY 1985

TECHNICAL PUBLISHING

Semiconductor design and manufacture

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20016

1985 Laboratory of the Year

Research & Development

SERVING THE $202-BILLION WORLDWIDE R&D INDUSTRY

Work in a 'people place.' See p 90.

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ABOUT THE COVER

"I would enjoy working there. I think that my work there would be really productive . . . " The GE Plastics Technology Center in Pittsfield, MA, is *Research & Development* magazine's 1985 Laboratory of the Year.

The facility was designed to promote communications by identifying the special relationships between labs, and providing public places for informal interdisciplinary discussions by technical workers, scientists, and managers.

The three sections of the lab are joined by barrel-vaulted corridors and galleria. The curved lines are carried over into the center's landscaping and access roads.

High Honors go to the Exxon Research & Engineering Co.'s Research & Headquarters Facility, Annandale, NJ.

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ABP BPA

R&D INCOME WINNER: MALE PhD IN INDUSTRY

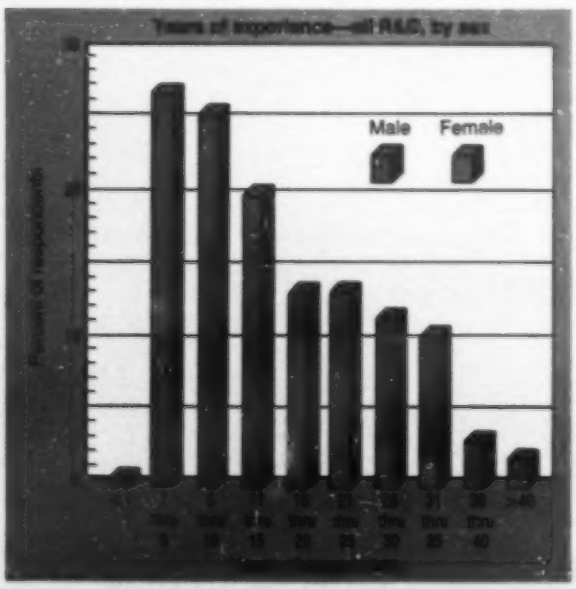
Career premium for doctorate increases substantially; women lag in salary sweepstakes, but are closing the gap.

Robert R. Jones, Editor

THE LARGE NUMBERS that the R&D industry associates with PhD salaries got substantially larger last year, and the salary advantages of other levels of education reflect similar industry response.

To the extent that the nearly 3,700 respondents to our recent survey of the R&D industry are representative, we can say that the research and development scientist or engineer with a doctoral degree can expect a career income advantage of $715,000 over his R&D colleague who did not go beyond the baccalaureate level. This figure compares to the $620,000 derived from our survey last year.

Respondents to our survey have made it clear that the net value of a PhD over a BS depends on an individual's field of endeavor and sex, and whether the employer is from industry, academia, or government. Considering that the figure cited above is based on a median for our respondents, it is easy to see that many PhDs will show much larger benefits than this from their doctorates.



The $715,000 career benefit figure is what remains after we deduct costs of the added education and allow for the additional years spent in school. We assume that the holder of the PhD will work 25 years after getting that degree, a figure that our survey shows is conservative. If the comparison were extended to show a 35-year work career, the difference in income would increase markedly, because returns to experience are substantial in the latter years of a career, as we demonstrated in the first part of this article in March.

However, sticking with the conservative 25 years for the PhD, we allow a 30-year career for the person who enters the work force after getting a BS. Assuming a 10% interest rate prevailing over the 25-year career of the PhD and allowing $300,000 for tuition, missed earnings, etc., we then can make appropriate projections. From this comes the PhD's career benefit figure.

Using similar calculations with different allowances for earning years and expenses, we find that the present career value of a PhD over an MS is $470,000, just $100,000 higher than it was a year ago.

For the high school graduate who is wondering about college, the message is, "Go for it!" The net career benefit for a BS over less-than-BS is a cool half million dollars—cool, because that figure is rounded off from the $565,000 indicated from our responses. And we would point out to that high schooler that the less-than-BS person that we are comparing here had to be able to get a job in R&D and qualify as a researcher in order to be included in this survey at all.

"Raises, schmaizes, Dean Oberholdt! Our women researchers still get only three-fourths of what they would get in industry!"

Separate from the personal benefits that accompany a bachelor degree, the extra two, three, or four years necessary to go from less-than-BS to having that diploma would return to a typical individual a minimum of $141,000 per year invested.

Adding an MS to the BS is worth another $250,000 over a career, or roughly $8,000 every year. And the benefit of PhD over less-than-BS over the PhD's 25-year career works out to more than a million dollars ($1,092,000 compared to $875,000 last year).

And there are other interesting and helpful conclusions that can be drawn from our survey of salaries in relation to highest academic degree, as you will see in this table:

Salaries compared by academic degrees

Degree	Median salary 1985	Median salary 1984	Percent change	Annual difference* 1985	Annual difference* 1984	Difference increase (percent)
Doctorate	$45,720	$43,200	+5.8	$5,280	$5,280	+17.4
Master	39,520	37,920	+4.2	3,180	3,210	− 0.9
Bachelor	36,340	34,710	+4.7	4,870	3,760	+29.5
<Bachelor	31,470	30,950	+1.7			

*Difference above next-lower degree

As has been true in recent years, the income advantages of baccalaureate and advanced degrees have been increasing faster than the rate of inflation. Last year the median income for less-than-BS did not keep up with inflation. Thus, the advantage for a PhD over less-than-bachelor in annual income increased to $14,250 last year from $12,250 the year before.

Reference was made earlier to the fact that these are all median figures, and that many PhDs will earn substantially more than the figures cited. By the same token, there will be some who earn substantially less, and a large portion of those will be women.

As we have pointed out for a number of years, women who work in research, development, and quality assurance earn a lot less than men do. That is not to say that they always earn less for equal work. For many reasons the female work force cannot be compared directly to their male counterparts.

Because of differences in opportunities, women almost always have less experience than men in R&D and QA. They usually have less time with their present employers, and they usually have less education. Thus, the higher paying jobs tend to be occupied by males with advanced degrees and substantial work experience.

When all of the differences are balanced out, we find that the male R&D worker in industry is earning a median annual salary of $41,750 in contrast to the female worker in a university where the median salary is $24,040.

Looking at salaries for workers in R&D and QA by sex and workplace, we find important differences from government to industry to university. One important change here is that government has recently relinquished some of its traditional salary leadership to industry. This first occurred last year.

Another important difference in salary ranges is that the lowest male median still exceeds the highest female median. The rankings are as follows:

	1985	1984	% gain
Men in industry	$41,750	$39,200	6.5
Men in government	40,400	38,630	4.6
Men in universities	38,040	32,580	16.8
Women in industry	31,590	29,590	6.8
Women in government	33,130	29,450	12.5
Women in universities	24,040	20,450	17.8

In this year's survey, the median annual income for all males is $40,990, up from $38,440 last year, and for all females it is $31,130, compared to last year's

$28,990; a 6.6% gain for males and 7.4% for females.

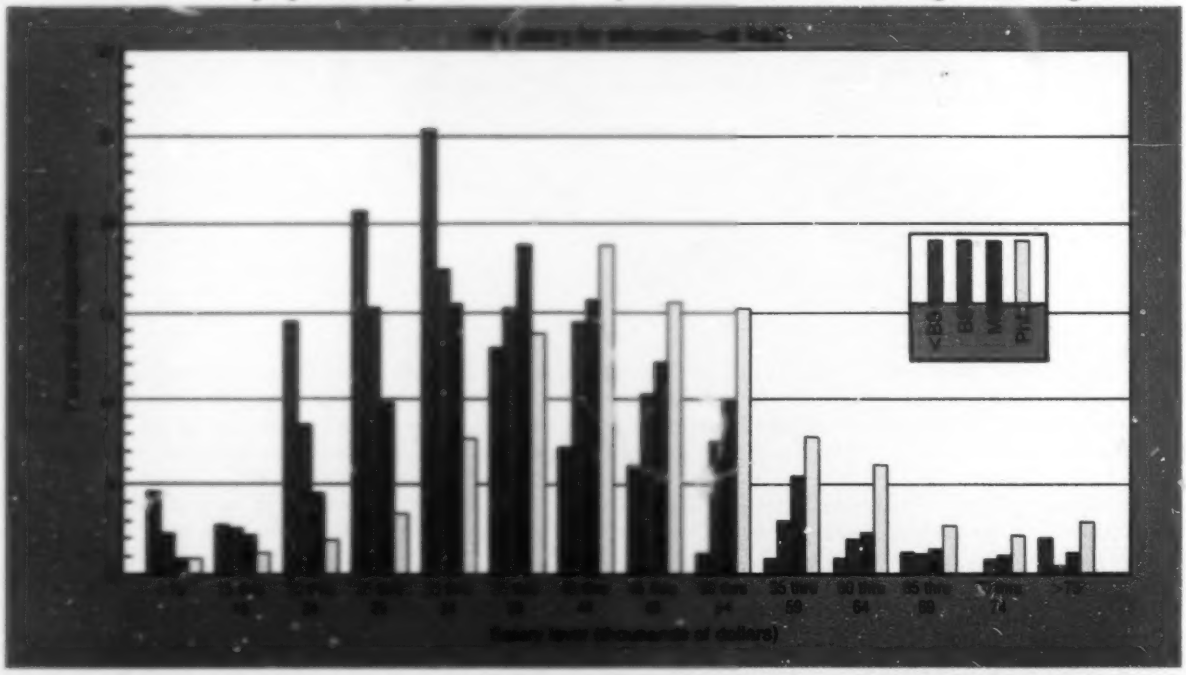
As we mentioned when comparing salaries by sex, the long-standing practice of government agencies paying the highest salaries for comparable work has changed. It is too early to say that it has ended, but in any case we can look at these comparisons for all respondents:

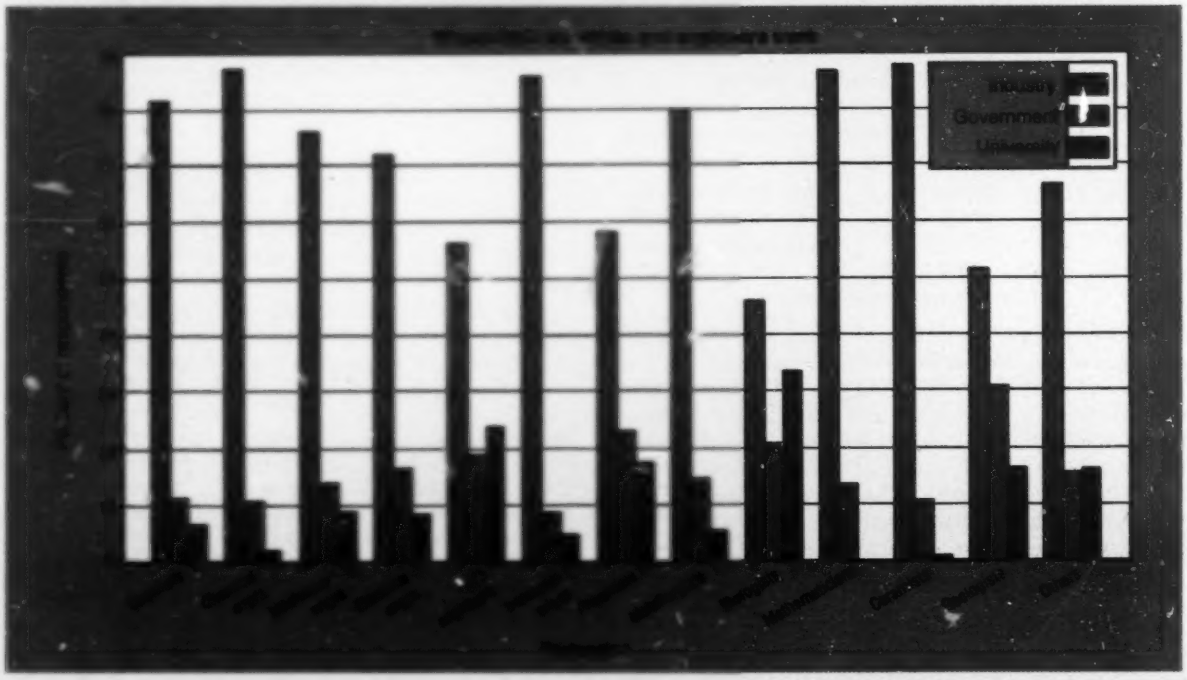
Median salaries all R&D by workplace

	1980	1984	1985
Government	$29,733	$38,210	$39,790
Industry	28,354	38,550	40,980
University	25,685	31,890	34,950

Granted, there are proportionately more women working in the universities, but there are proportionately more PhDs in the universities, too, and we have demonstrated above that they draw substantially higher salaries. One could expect this latter factor to balance the former, but obviously it is not strong enough to bring the university pay scale into line with that of industry.

Salary increases for all R&D last year were much stronger in the middle ranges than they were a year earlier. More than 18% of men and women received no salary increase or raises of less than 2% in the earlier year. Last year only a little more than 12% fell into that below-inflation range. And, as we could report last year, women were much stronger in the large increase





portion of the table, suggesting that some repair is being made to the long-standing disparities. Here are the details:

Salary increases by sex

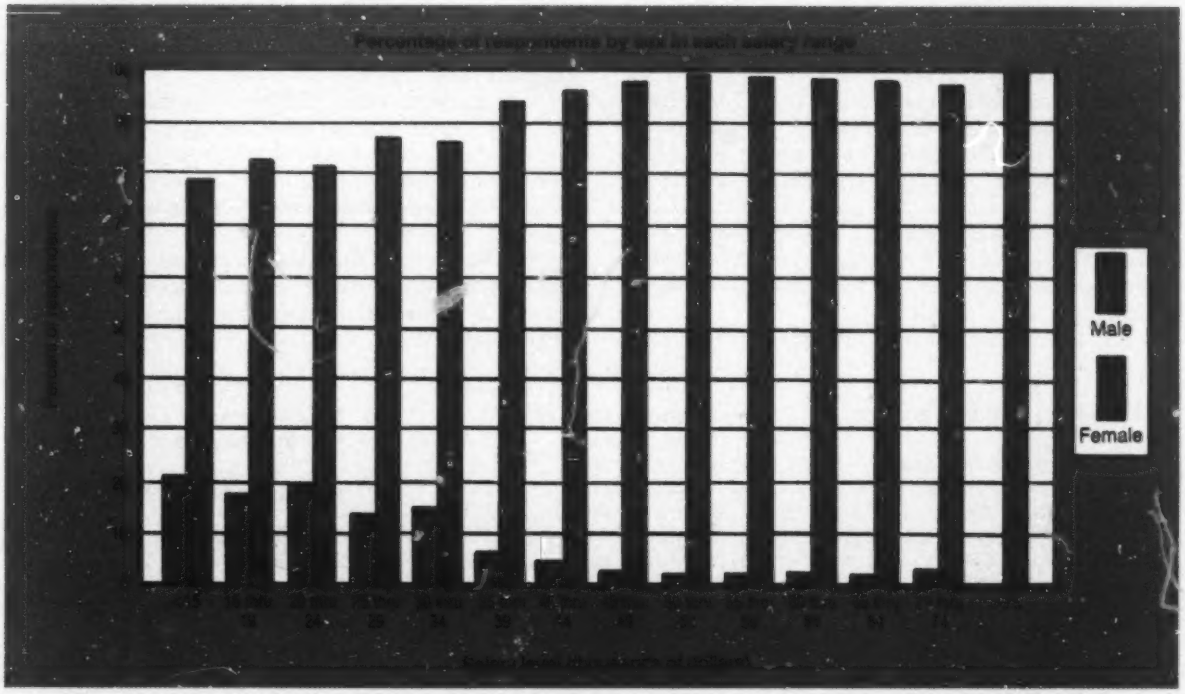
Amount	1983 %		1984 %	
	Male	Female	Male	Female
None	16.3	15.6	9.4	8.6
Less than 2%	2.0	2.7	2.8	3.7
2 through 5%	27.3	20.5	36.6	35.2
6 through 9%	38.9	39.5	37.8	34.5
10 through 13%	11.2	15.6	9.8	14.6
14% or more	4.3	6.1	3.6	3.4

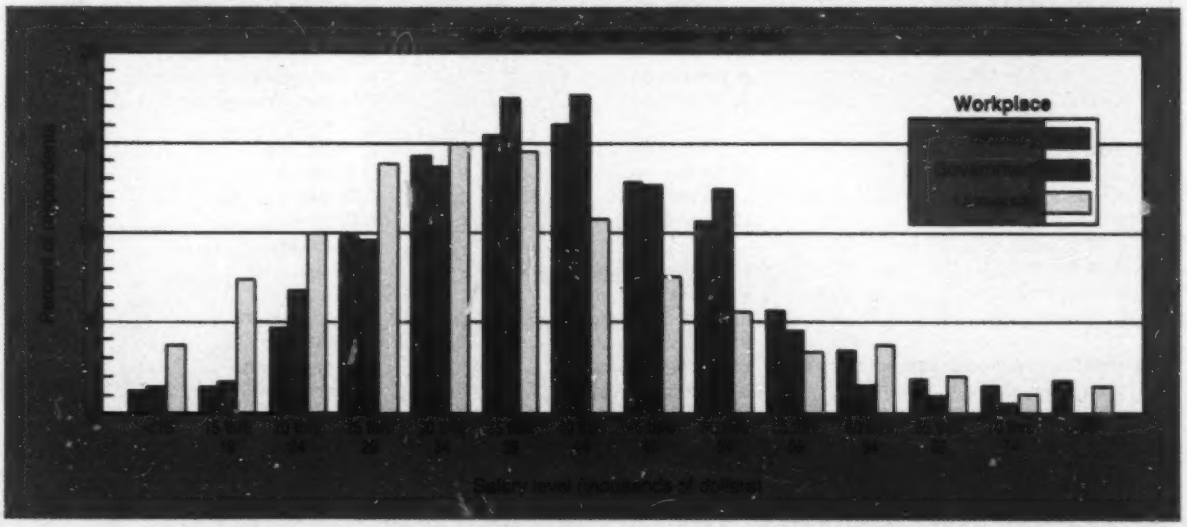
As we reported in Part I of this article, the ranges were changed on our salary questions, and the reasons were explained in detail. Where last year we reported on annual earnings above $31,000, this year we can only approximate a comparable report.

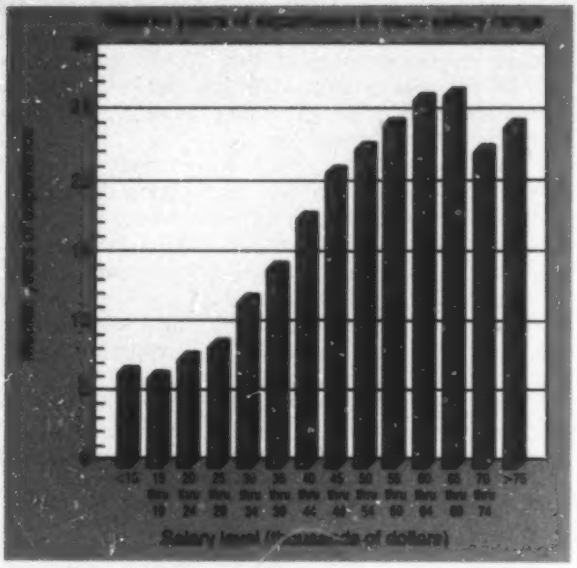
Last year some 37.7% of the women respondents were earning $31,000 per year or more. This year's women respondents report that 56.6% are earning $30,000 per year or more. Our interpolation puts the figure this year for $31,000 or more at near 51%, strikingly above that of a year ago.

Men dominate the upper salary ranges, as would be expected from all that has been said in these paragraphs about premiums paid for advanced degrees, age, and experience. More than 75% of male repondents last year were earning $31,000 per year or more. This year's figure is 80.4% earning $30,000 per year or more, with our interpolation putting those earning $31,000 or more at 77.6%. This is nowhere near the rate of increase that women showed.

As you would expect, our chart shows that women working in research, development, and quality assurance lag far behind men in work experience. Median







years of experience for males in R&D is 17.0 years, up from 16.73 last year and several previous years. For women, the median years of experience is 9.12, up from the 7.86 that had been reported in several previous years.

There is a large reservoir of experience among males in R&D, with 41.5% having more than 20 years' experience. This represents a continuation of small increases reported in recent years

Just over a third of that percentage, or 15.9% of the female respondents, report having 20 years' experience in their prese t work, approximately the same as in recent years.

The fact that many of the female respondents are young controls the experience figure. For a large portion, 20 years of experience would be impossible, since 71.1% are younger than 40 years of age. Only 43.7% of the men are that young.

One result of the younger age range for females is that there are fewer in the work force with PhDs. The percentage of female respondents this year with PhDs is 19.1, up substantially from last year's 14.8, and in line with earlier years. Of this year's male respondents, 34.4% report having a PhD, up from close to 32% in recent years.

The time spent with the same organization usually is a plus when it comes to salary. The fact that 5.9% of the male respondents have been with their present employer for more than 30 years helps to explain their higher positions in the organization and on the pay scales. Only 1.2% of this year's female respondents have the same longevity.

At the same time, 55.7% of this year's female respondents are reporting less than seven years with the same organization, down slightly from last year and in line with previous years. Only 37.5% of the males have been with their present employer for less than seven years.

A wealth of additional information about the men and women who work in research, development, and quality assurance is contained in the accompanying charts and tables. R&D

1985 R&D Industry profile:

1. What is your annual salary?

a. Less than $15,000	1.6%
b. $15,000 to $19,999	2.0
c. $20,000 to $24,999	5.7
d. $25,000 to $29,999	10.3
e. $30,000 to $34,999	14.2
f. $35,000 to $39,999	15.5
g. $40,000 to $44,999	15.7
h. $45,000 to $49,999	12.2
i. $50,000 to $54,999	10.2
j. $55,000 to $59,999	5.1
k. $60,000 to $64,999	3.3
m. $65,000 to $69,999	1.6
n. $70,000 to $74,999	1.2
o. $75,000 or more	1.5

2. Your raise during the past year was ...

a. None	9.3%
b. Less than 2%	2.9
c. 2 thru 5%	36.6
d. 6 thru 9%	37.6
e. 10% thru 13%	10.1
f. 14% or more	3.6

3. How long have your worked for your present employer?

a. Less than 1 year	4.4%
b. 1 thru 3 years	16.6
c. 4 thru 6 years	17.8
d. 7 thru 9 years	11.7
e. 10 thru 12 years	9.4
f. 13 thru 15 years	7.6
g. 16 thru 18 years	7.7
h. 19 thru 21 years	6.5
i. 22 thru 24 years	5.9
j. 25 thru 27 years	4.1
k. 28 thru 30 years	2.7
m. 31 thru 33 years	3.3
n. 34 thru 36 years	1.3
o. More than 36 years	1.0

4. What is your age?

a. Under 26	2.2%
b. 26 thru 30	10.4
c. 31 thru 35	15.5
d. 36 thru 40	17.5
e. 41 thru 45	14.9
f. 46 thru 50	13.2
g. 51 thru 55	11.6
h. 56 thru 60	9.0
i. 61 thru 65	4.3
j. Over 65	1.4

5. How many years of experience do you have?

a. Less than 1 year	0.6%
b. 1 thru 5 years	12.0
c. 6 thru 10 years	17.2
d. 11 thru 15 years	17.0
e. 16 thru 20 years	13.6
f. 21 thru 25 years	13.4
g. 26 thru 30 years	11.2
h. 31 thru 35 years	9.8
i. 36 thru 40 years	3.3
j. More than 40 years	1.9

6. What is the highest degree you hold?

a. Less than bachelor	7.1%
b. Bachelor	34.2
c. Master	25.6
d. Doctorate	33.1

7. What is your profession?

a. Chemist	37.4%
b. Chemical engineer	7.0
c. Mechanical engineer	9.3
d. Electrical engineer	8.9
e. Aeronautical engineer	1.5
f. Industrial engineer	1.1
g. Physicist	9.0
h. Metallurgist	5.2
i. Biologist	6.2
j. Mathematician	0.4
k. Ceramist	1.8
m. Geologist	1.5
n. Other	10.6

8. Do you work in ...

a. Industry	74.1%
b. Government	15.1
c. University	10.9

9. Are you ...

a. Male	92.7%
b. Female	7.3